ORIGINAL RESEARCH ARTICLE

Augmenting climate-resilient energy infrastructure through National and International Standards for Renewables

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Abstract
Kenya's Energy sector has an installed capacity of 3.601 GW (grid-connected 3.321 GW and captive 280.76 MW), with 80.48% coming directly from Renewable energy sources. This huge percentage of renewable energy in the energy mix, however, is not reflected in the adoption or development of Standards. Standards help enhance the safety and efficiency of products, security, and quality assurance while ensuring interconnectivity and interoperability of components. Standards enable the dissemination of new technologies, good practises, and ultimately a climate-resilient energy infrastructure (CREI). To achieve CREI, standards act as a catalyst for advancing the attainment of economies of scale for renewables while also providing technical specifications to accelerate their deployment. This study thus addresses the ominous gap that exists due to the lack of a proper standard inventory across all renewables. In this way, this work addresses the irregular and at times inconsistent gap between the direct causal link between policy and standards on the one side and application areas such as management, information systems, and social use of renewable energy on the other. The study employed the Mixed Methods Research (MMR) approach to enable an understanding of the Renewable Energy (RE) standards environment in Kenya. In addition, realistic literature reviews and meta-analysis literature reviews were employed to deal with complex standards within the renewable energy sector. The study demonstrated that in the majority of Renewable Energy Technologies (RETs), major gaps in terms of standards exist for various RETs, the import of this being that the majority of RETs cannot be manufactured locally. The study also concludes that a low awareness exists of standard implementation, and further, due to a lack of awareness of technological innovations on the global level, the development of national standards and capacity building of competent staff (including techno-financial support for renewable energy technologies) have been significantly hampered. Subsequently, the study does appreciate the role of universities and higher educational institutions as being central in the research and analysis of renewable energy technologies as well as the adaptation and/or adoption of local and international standards.

Keywords: Standards, Renewable Energy, Energy mix, Climate-resilience,

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1.0 Introduction

Kenya as a country has an interesting energy mix, with almost 74.93% of the 3,601.86 MW installed being from renewable energy resources and the remaining being from thermal-based fossil fuels (19.52%) and imports (5.55%). The thermal-based fuels comprise 703.23 MW. This energy mix is depicted in Fig. 1.

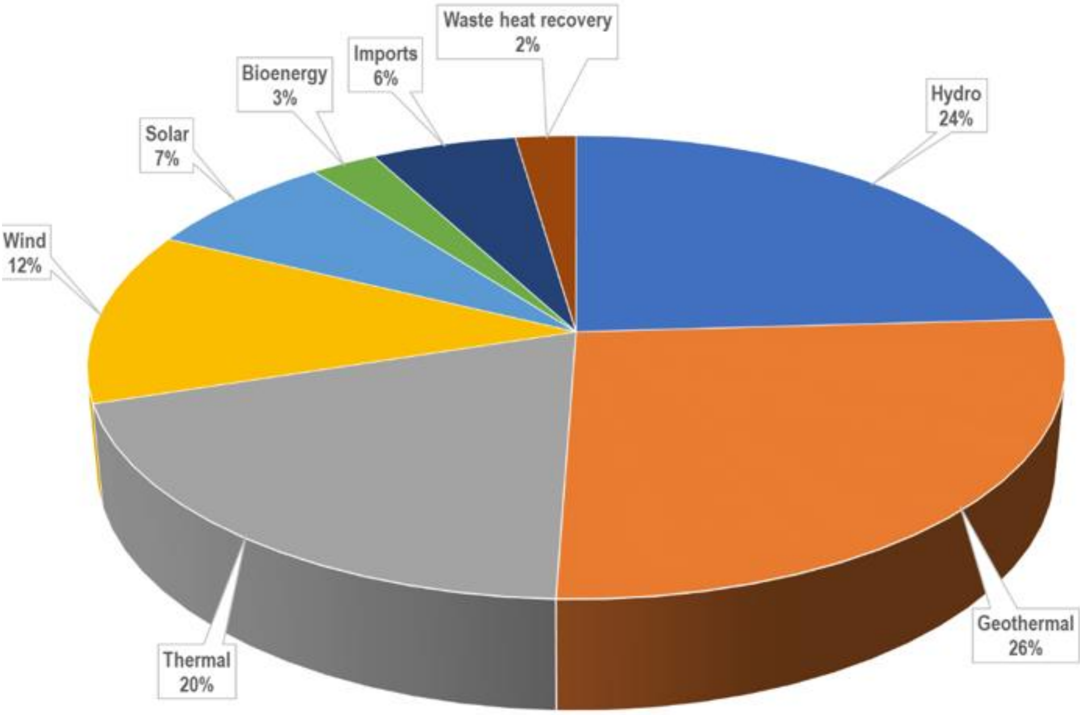

Fig 1: Energy mix for Kenya

(EPRA, 2022)

One of the challenges of the commonly used energy mix is that it does not denote how the technology is performing in the market. In this sense, it only provides information about the system that has been installed or decommissioned. In-depth information on the quality of the system is lacking. One such way of understanding the quality of Renewable Energy installations is through an analysis of the national and international standards available in the country. Unfortunately, such studies have not been easily available to enable investors to understand the regulatory framework to be complied with. This review study thus seeks to address this research gap by undertaking an in-depth, comprehensive review of standards applied in Kenya's Renewable Energy sector.

The following sub-sections thus analyse in depth the standard's availability of potential and existing RETs (excluding geothermal and thermal power plants).

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2.0 Methods and tools

2.1 Research approach

Data and information presented in this study were collected through mixed methods. The research approach is delineated in a three-step approach: (a) Literature or Desktop review that employs meta-analysis and Realist literature review; (b) Field data collection; and (c) Data analysis or synthesis.

Fundamentally, the study aims to take inventory of the available standards and specifically determine what "works". The determination of a direct causal link between policy and standard interventions in relation to outcomes in application areas of management, information systems, and social policy has been noted to be irregular or inconsistent (Paré and Kitsiou, 2017). To address this demerit, realist literature reviews (RLS) were historically proposed (Pawson et al., 2005).

The thrust of realist reviews is to deal with complex interventions, such as a study of standards within the renewable energy sector. It transforms the ordinary question asked in policy and standards research work from what works to (a) the intervention that works, (b) for whom it works, (c) the various circumstances and contexts that it works under, and lastly, (d) why it works.

Realist reviews focus on either or both qualitative and quantitative evidence. At its core, the RLS first identifies the likely underlying working theories and approaches and then builds on them by analysing available literature evidence to verify whether and where these approaches are applicable (Shepperd et al., 2009). The use of case studies in this regard has been found quite useful in testing and modifying the initial approaches (Otte-Trojel et al., 2014; Rousseau et al., 2008).

2.2 Methodology

In this study (Fig. 2), the process was initiated by an exploratory review of the background literature to identify which standards exist nationally, regionally, and internationally as pertains to RETs. Thereafter, a formal identification process will need to be undertaken to identify parameters and ways of assessing the outcomes of standards in the Renewable Energy (RE) Sector. A few of these parameters included compliance levels, stakeholder contribution to standard development, and non-compliance levels, among others. The formulation of such parameters will, however, be informed by reviews of existing literature and corresponding case studies.

The key methods include: (a) Meta-analysis to undertake a literature review; (b) field data acquisition; (c) Market mapping and analysis tool to identify and map the primary value chain players and stakeholders in the renewable energy market; and lastly, (d) Problem tree analysis to cluster and illustrate the main gaps and policy solutions. These Policy solutions may be clustered into technical, financial, policy, and regulatory categories. Detailed graphical descriptions of the tools and methods used for both baseline studies are shown in Fig. 3.

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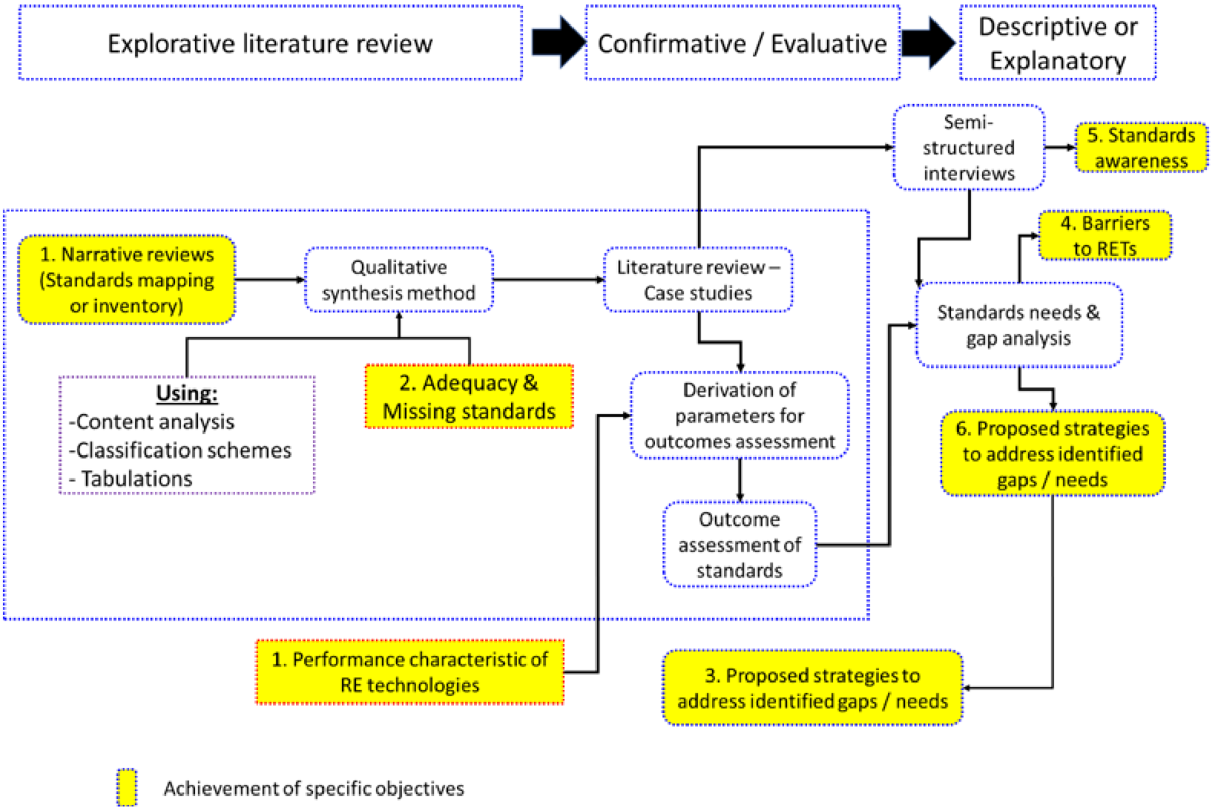

Fig 2: Methodology for achieving the baseline study on Standards

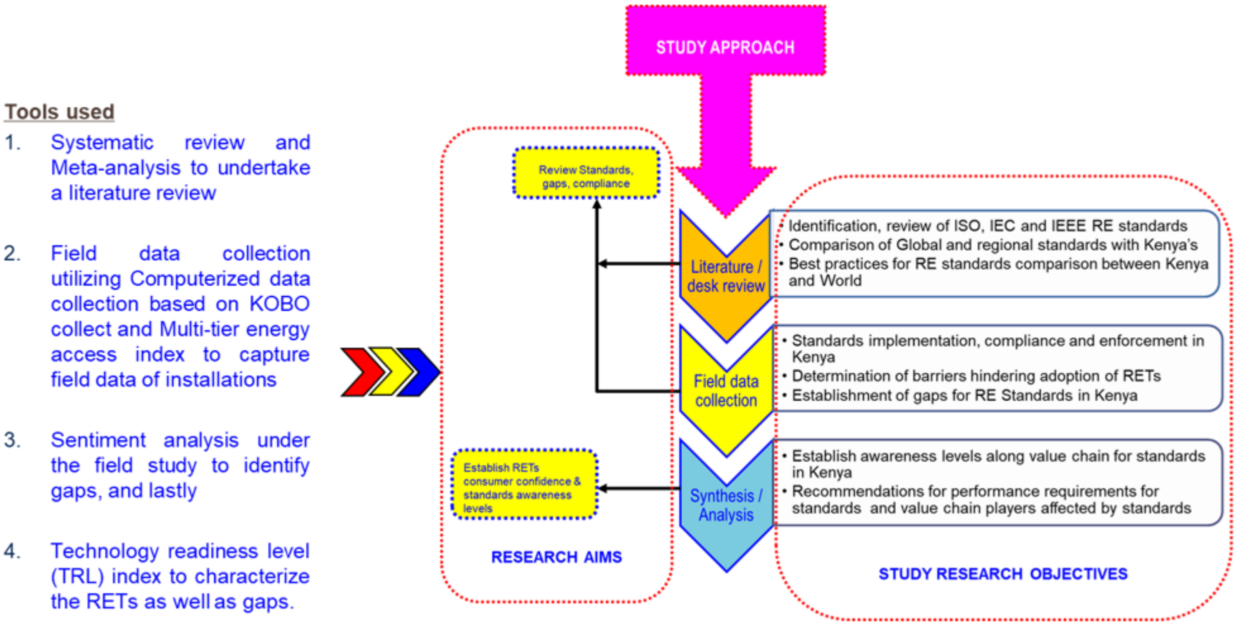

Fig 3: Methods and tools for the national standards baseline study

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3.0 Results and discussion

3.1 Renewable energy technologies capacity and potential

This section presents the first (standards inventory) in totality. The second objective, by way of the inventory, indicates those international standards that have been adopted for use within the Kenyan Renewable Energy Sector.

Implicitly, those standards that have not been adopted or national standards developed to meet those needs are deemed to be part of the gaps that should be addressed. The remaining objectives under the capacity projects, including Renewable Energy performance characteristics indicators, shall be addressed in conjunction with the field studies. The renewable technologies considered for this study are shown in Fig. 4.

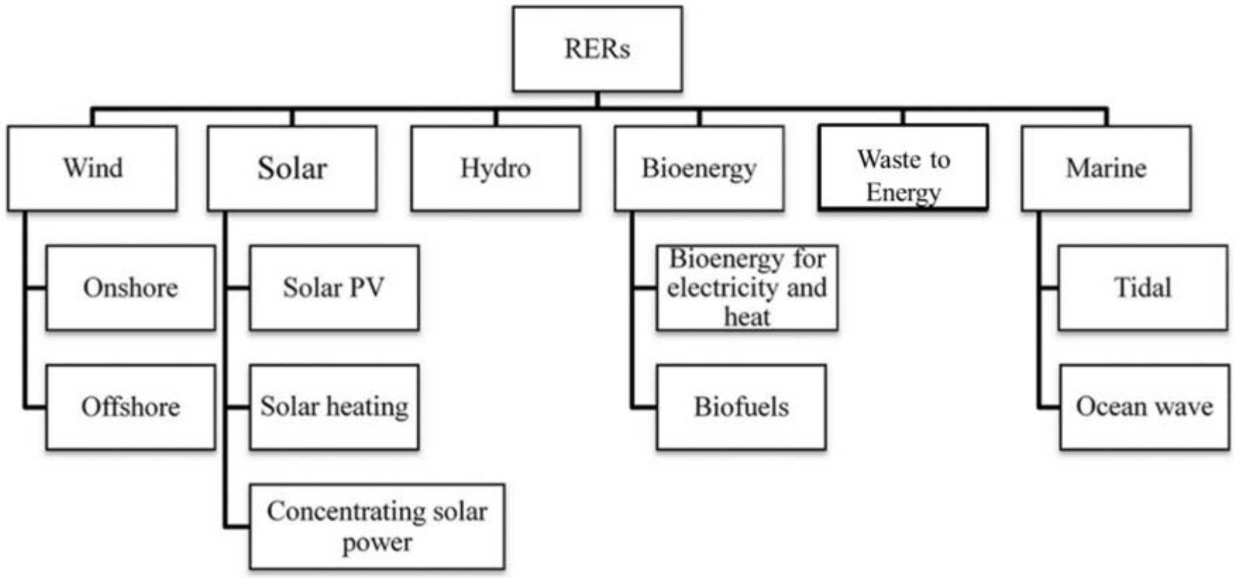

Fig 4: Renewable Energy Technologies considered in this standards inventory study

3.2 Tidal and ocean power (marine and energy) standards capacity

3.2.1 Potential resource assessment

Generally, the development of Tidal and Ocean power has previously focused on oceans and seas and not on inland water bodies like lakes and rivers. Studies by (AfDB, 2021) have indicated that Kenya and Eastern Africa in general have an exceptionally diverse and high potential for offshore renewables, which, due to technical and/or deficit standards, have not been exploited. Such offshore renewables include wave power, Ocean thermal Energy Converters (OTEC), offshore wind turbines, ocean current power, tidal wave systems, and marine floating Photovoltaic (FPV).

In Kenya, the technical potential for exploitation of Tidal and Ocean power can be estimated between 7 GW and 5 GW per metre of coastline length, depending on whether a modest coastline length of 589 km or the full length of 1,420km is used (Table 1). The unit potential power in kW/m is obtained from (AfDB, 2021), which categorises the potential for locations close to shore (10 km) and at depths of about 50 m or less.

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Table 1: Technical potential of Tidal and Ocean power along the Kenyan Coast

County	Coastline length (m)	Unit potential (kW)/coastline (m)	Technical potential (GW)
Lamu	130,000	8	1.04
Tana River	35,000	7	0.245
Kilifi	109,000	7	0.763
Mombasa	65,000	7	0.455
Kwale	250,000	7	1.75
Average coastal length	589,000	7	4.123

(AfDB, 2021)

3.2.2 Standards

Kenya is currently deficient in the development and/or adoption of International Marine and Tidal wave standards (Table 2). This is in part attributed to a lack of funding as well as the fact that no pilot technology is currently employed or piloted across the country. Other reasons include a lack of training programmes, research, and innovation in these areas. Recent studies have revealed that along the Kilifi and Lamu coastlines, near-shore wave technical potential and capacity power are at 7 kW/m and 8 kW/m, respectively. With a shoreline of about 130 km for Lamu and 109 km for Kilifi (AfDB, 2021).

3.3.3 Gaps in Tidal and Ocean Power Standards

Analysis of the deficit standards to support the development of Ocean and Tidal power systems that need to be adopted or adapted to the Kenyan Scenario includes the below-listed technologies in Table 2, but excludes Ocean thermal Energy Converters (OTEC), offshore wind turbines, and marine floating Photovoltaic (FPV).

Table 2: Standards for Tidal, wave and other water current converters

Standard No.	Title
IEC TS 62600-1:2020	Marine energy- Wave, tidal and other water current converters- Part 1: Vocabulary
IEC TS 62600-2:2019	Marine energy- Wave, tidal and other water current converters- Part 2: Marine energy systems- Design requirements
IEC TS 62600-3:2020	Marine energy- Wave, tidal and other water current converters- Part 3: Measurement of mechanical loads
IEC TS 62600-4:2020	Marine energy- Wave, tidal and other water current converters- Part 4: Specification for establishing the qualification of new technology
IEC TS 62600-10:2021	Marine energy- Wave, tidal and other water current converters- Part 10: Assessment of mooring system for marine energy converters (MECs)
IEC TS 62600-20:2019	Marine energy- Wave, tidal, and other water current converters- Part 20: Design and analysis of an Ocean Thermal Energy Conversion (OTEC) plant- General guidance
IEC TS 62600-30:2018	Marine energy- Wave, tidal and other water current converters- Part 30: Electrical power quality requirements
IEC TS 62600-40:2019	Marine energy- Wave, tidal and other water current converters- Part 40: Acoustic characterization of marine energy converters
IEC TS 62600-100:2012	Marine energy- Wave, tidal and other water current converters- Part 100: Electricity producing wave energy converters- Power performance assessment

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Standard No.	Title
IEC TS 62600-101:2015	Marine energy - Wave, tidal and other water current converters - Part 101: Wave energy resource assessment and characterization
IEC TS 62600-102:2016	Marine energy - Wave, tidal and other water current converters - Part 102: Wave energy converter power performance assessment at a second location using measured assessment data
IEC TS 62600-103:2018	Marine energy - Wave, tidal and other water current converters - Part 103: Guidelines for the early-stage development of wave energy converters - best practices and recommended procedures for the testing of pre-prototype devices
IEC TS 62600-200:2013	Marine energy - Wave, tidal and other water current converters - Part 200: Electricity producing tidal energy converters - Power performance assessment
IEC TS 62600-201:2015	Marine energy - Wave, tidal and other water current converters - Part 201: Tidal energy resource assessment and characterization
IEC TS 62600-202:2022	Marine energy - Wave, tidal and other water current converters - Part 202: Early-stage development of tidal energy converters - Best practices and recommended procedures for the testing of pre-prototype scale devices
IEC TS 62600-300:2019	Marine energy - Wave, tidal and other water current converters - Part 300: Electricity producing river energy converters - Power performance assessment
IEC TS 62600-301:2019	Marine energy - Wave, tidal and other water current converters - Part 301: River energy resource assessment
Under development	Ocean thermal energy conversion standards
offshore wind turbines	Addressed under the Wind turbine section
marine floating Photovoltaic (FPV)	Addressed under the Solar PV section

3.3.4 Hydropower standards

3.4.4.1 Potential resources assessment

As a country, the digital elevation presents a huge opportunity to enable the development of the hydropower sector. With complex terrain in the mid-centre that plays out as you approach the major water bodies of Lake Victoria, Lake Turkana, and the Indian Ocean (Fekete, 2022), Currently, Kenya's installed hydropower capacity is estimated at 0.8267 GW. Based on Vision 2030, Kenya is expected to almost double its Hydropower capacity mix by 0.977 GW (54.8%), up from the 2017 value of 0.805 GW. With an estimated capacity of between 3 GW and 6 GW, about 1.449 GW is technically feasible for large hydropower systems (Wako, 2020). It is noteworthy that the projects considered are those with 30 MW capacity or more. Considering the potential advent of large hydropower projects (those with a capacity of 10 MW or above) (Kenya, 2019a), it becomes necessary to have local standards that address large hydropower projects. It is estimated that 51 large hydropower projects could be developed in the coming decade(s). Thus, local standards for large hydropower projects will be required.

Table 3: Number of large hydro projects in Kenya

Basin	Total installed capacity (MW)	Number of projects
Lake Victoria basin	329	11
Rift valley Basin	305	11
Athi River Basin	60	2
Tana River Basin	790	27

(Wako, 2020)

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For a small hydropower (SHP) system, the country has seen quite a several independent power producers (IPP) establishing such plants. Less than 30 MW of SHP systems have been installed in Kenya with about 15 MW being connected to the grid (Wako, 2020)

3.3 Standards

3.3.1 Standards adopted or adapted in Kenya

With regards to standards, the country has focussed on small hydro power standards with an evident gap in big hydro standards. Kenya has 6 locally developed or adapted standards (Table 4).

Table 4: Local Kenyan small hydropower standards

	Reference	Title
1.	KS IWA 33-1:2019	Technical guidelines for the development of small hydropower plants Part 1: Vocabulary
2.	KS IWA 33-2:201	Technical guidelines for the development of small hydropower plants Part 2: Site selection planning
3.	KS IWA 33-3:2021	Technical guidelines for the development of small hydropower plants Part 3: Design principles and requirements
4.	KS IWA 33-3:2021	Small-scale hydropower systems design guidelines Part 5: Environmental impact analysis and mitigation
5.	KS IWA 33-3:2021	Small-scale hydropower systems design guidelines Part 6: Public safety

In addition to these, several international standards on Small hydropower have been adopted for the Kenyan environment (Table 5).

Table 5: Adopted general and small hydropower standards in Kenya

Reference	Title
IEC 60545:2021	Guidelines for commissioning and operation of hydraulic turbines, pump-turbines and storage pumps
IEC 61116:1992	Electromechanical equipment guide for small hydroelectric installations
KS IEC 62006:2010	Hydraulic machines- Acceptance tests of small hydroelectric installations
IEC 63132-1:2020	Guidance for installation procedures and tolerances of hydroelectric machines- Part 1: General aspects
IEC 63132-2:2020	Guidance for installation procedures and tolerances of hydroelectric machines- Part 2: Vertical generators
IEC 63132-3:2020	Guidance for installation procedures and tolerances of hydroelectric machines- Part 3: Vertical Francis turbines or pump-turbines
IEC 63132-4:2020	Guidance for installation procedures and tolerances of hydroelectric machines- Part 4: Vertical Kaplan or propeller turbines
ISO 20816-5:2018	Mechanical vibration- Measurement and evaluation of machine vibration- Part 5: Machine sets in hydraulic power generating and pump-storage plants

3.3.2 Gaps in Hydropower standards

The following standards (Table 6) thus require adoption or adaptation to the Kenyan situation to enable the growth and development of particularly Large / Big hydropower systems

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Table 6:Hydropower standards requiring adoption or adaptation in Kenya

Reference	Title
IEC 60041:1991	Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines
IEC 60193:2019	Hydraulic turbines, storage pumps and pump-turbines- Model acceptance tests
IEC 60308:2005	Hydraulic turbines- Testing of control systems
IEC 60609-1:2004	Hydraulic turbines, storage pumps and pump-turbines- Cavitation pitting evaluation- Part 1: Evaluation in reaction turbines, storage pumps and pump-turbines
IEC 60609-2:1997	Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump-turbines- Part 2: Evaluation in Pelton turbines
IEC 60994:1991	Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump-turbines)
IEC 61362:2012	Guide to the specification of hydraulic turbine governing systems
IEC TR 61364:1999	Nomenclature for hydroelectric powerplant machinery
IEC TR 61366-1:1998	Hydraulic turbines, storage pumps and pump-turbines- Tendering Documents- Part 1: General and annexes
IEC TR 61366-2:1998	Hydraulic turbines, storage pumps and pump-turbines- Tendering Documents- Part 2: Guidelines for technical specifications for Francis turbines
IEC TR 61366-3:1998	Hydraulic turbines, storage pumps and pump-turbines- Tendering documents- Part 3: Guidelines for technical specifications for Pelton turbines
IEC TR 61366-4:1998	Hydraulic turbines, storage pumps and pump-turbines- Tendering Documents- Part 4: Guidelines for technical specifications for Kaplan and propeller turbines
IEC TR 61366-5:1998	Hydraulic turbines, storage pumps and pump-turbines- Tendering Documents- Part 5: Guidelines for technical specifications for tubular turbines
IEC TR 61366-6:1998	Hydraulic turbines, storage pumps and pump-turbines- Tendering Documents- Part 6: Guidelines for technical specifications for pump-turbines
IEC TR 61366-7:1998	Hydraulic turbines, storage pumps and pump-turbines- Tendering Documents- Part 7: Guidelines for technical specifications for storage pumps
IEC 62097:2019	Hydraulic machines, radial and axial- Methodology for performance transposition from model to prototype
IEC 62256:2017	Hydraulic turbines, storage pumps and pump-turbines - Rehabilitation and performance improvement
IEC 62270:2013	Guide for computer-based control for hydroelectric power plant automation
IEC 62364:2019	Hydraulic machines- Guidelines for dealing with hydro-abrasive erosion in Kaplan, Francis and Pelton turbines
IEC TS 62882:2020	Hydraulic machines- Francis turbine pressure fluctuation transposition
IEC 63132-1:2020	Guidance for installation procedures and tolerances of hydroelectric machines- Part 1: General aspects

Apart from the large hydropower (>10 MW capacity) standards, additionally, a number of the key standards may need to be adapted or adopted for the Kenyan Scenario to address several issues, including

i. Digitization of hydropower plants Digital control systems and software, when adopted, tend towards equipment and turbine performance improvement, lowering costs, and improving asset management.
ii. Hybridization of hydropower with floating solar panels (FPV): The use of FPV allows for effective electricity and water management, particularly as it reduces water

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evaporation, saves money on grid integration, and increases the performance of Photovoltaics due to the reduced operating temperature.

iii. Pumped storage enables management of the intermittency and seasonality of variables from renewable sources like Wind and solar.

3.4 Wind Energy

3.4.1 Resource assessment

Wind resources in Kenya have been approximated at low (2.5m/s to 4m/s) to medium levels (4m/s to 6m/s). The reason has mainly to do with the country's topography. Generally, Kenya has low to medium-speed winds. However, there are pockets of high wind speeds, particularly within Marsabit, Turkana, and Kajiado counties. This can be attributed to topography like hill effects and Mesoscale flows like the low-level Turkana Jet wind in the Northern parts of the country.

The Northwest of the country (Marsabit and Turkana districts) and the Rift Valley edges are the two windiest areas (average wind speeds above 9 m/s at 50 m high). The coast and around Lake Victoria may also have economically viable wind speeds, albeit lower (about 5-7 m/s at 50 m high). Other local mountain spots, like Ngong Hills, offer good wind conditions. Nevertheless, wind resource variations are expected due to monsoon influence and seasonal variations (low winds between May and August in Southern Kenya). There is significant potential to use wind energy for grid-connected wind farms, isolated grids (through wind-diesel hybrid systems), and off-grid community electricity and water pumping.

Currently, the installed capacity in Kenya for operational grid-connected wind parks is about 449.1 MW (Table 7).

Table 7: Planned and operational Wind parks in Kenya

Wind park	County	Installed capacity (MW)	Commissioning year
Lake Turkana Wind park (LTWP)	Marsabit	310	Operational
Ngong Wind Park I	Kajiado	5.1 (Phase 1), 6.8 (Phase II)	Operational
Ngong Wind park II	Kajiado	13.6	Operational
Kipeto Wind Park	Kajiado	100	Operational
Ngong Wind park III	Kajiado	11	Operational
Chania Green	Kajiado	50	Operational
Meru (Isiolo) Wind farm	Meru	80	June 2023
Ol Ndanyat Power	Kajiado	10	Dec 2023
Aperture Green Power	Kiambu	50	June 2024
Prunus		50	Dec 2023

Further to the grid-connected wind turbines, Small wind turbines are also installed in Kenya, generally as part of PV-Wind hybrid systems. Studies indicate that about 80–100 small wind turbines with an installed capacity of 0.4 MW have been installed. Other studies indicate that off-grid wind systems have an installed capacity of 0.6 MW (Authority, 2020). Thus, the minimal total installed Wind energy systems are about 450 MW. Standards

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3.4.2 Standards adopted or adapted

The main standards adopted in Kenya include

Table 8: Wind Standards adopted or adapted in Kenya

Reference	Title
IEC 61400-1:2019	Wind energy generation systems- Part 1: Design requirements
IEC 61400-2:2013	Wind turbines- Part 2: Small wind turbines
IEC 61400-4:2012	Wind turbines- Part 4: Design requirements for wind turbine gearboxes
IEC 61400-11:2012+AMD1:2018 CSV	Wind turbines - Part 11: Acoustic noise measurement techniques
IEC 61400-12-1:2017	Wind energy generation systems - Part 12-1: Power performance measurements of electricity-producing wind turbines
IEC 61400-13:2015+AMD1:2021 CSV	Wind turbines- Part 13: Measurement of mechanical loads
IEC TS 61400-14:2005	Wind turbines- Part 14: Declaration of apparent sound power level and tonality values
IEC 61400-21-1:2019	Wind energy generation systems- Part 21-1: Measurement and assessment of electrical characteristics- Wind turbines
IEC 61400-23:2014	Wind turbines- Part 23: Full-scale structural testing of rotor blades
IEC 61400-24:2019	Wind energy generation systems- Part 24: Lightning protection
IEC 61400-25-1:2017	Wind energy generation systems- Part 25-1: Communications for monitoring and control of wind power plants - Overall description of principles and models
IEC 61400-25-2:2015	Wind turbines- Part 25-2: Communications for monitoring and control of wind power plants- Information models
IEC 61400-25-3:2015	Wind turbines- Part 25-3: Communications for monitoring and control of wind power plants- Information exchange models
IEC 61400-25-4:2016	Wind energy generation systems- Part 25-4: Communications for monitoring and control of wind power plants- Mapping to communication profile
IEC 61400-25-5:2017	Wind energy generation systems- Part 25-5: Communications for monitoring and control of wind power plants- Compliance testing
IEC 61400-25-6:2016	Wind energy generation systems- Part 25-6: Communications for monitoring and control of wind power plants- Logical node classes and data classes for condition monitoring

3.4.3 Gaps in wind energy standards

The main gaps in wind standards are in the broad areas of offshore wind turbines, manufacturing, and verification of wind turbine blades, towers, foundations, and nacelles. In addition, Power performance and site identification and calibration (including wind measuring campaigns and their tools) are yet to be adopted or adapted (Table 9).

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Table 9: Wind standards not adopted or adapted

Reference	Title
IEC 61400-3-1:2019	Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines
IEC TS 61400-3-2:2019	Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines
IEC 61400-5:2020	Wind energy generation systems – Part 5: Wind turbine blades
IEC 61400-6:2020	Wind energy generation systems – Part 6: Tower and foundation design requirements
IEC 61400-12-2:2013	Wind turbines – Part 12-2: Power performance of electricity-producing wind turbines based on nacelle anemometry
IEC TR 61400-12-4:2020	Wind energy generation systems – Part 12-4: Numerical site calibration for power performance testing of wind turbines
IEC TR 61400-21-3:2019	Wind energy generation systems – Part 21-3: Measurement and assessment of electrical characteristics – Wind turbine harmonic model and its application
IEC TS 61400-25-71:2019	Wind energy generation systems – Part 25-71: Communications for monitoring and control of wind power plants – Configuration description language
IEC 61400-26-1:2019	Wind energy generation systems – Part 26-1: Availability for wind energy generation systems
IEC 61400-27-1:2020	Wind energy generation systems – Part 27-1: Electrical simulation models – Generic models
IEC 61400-27-2:2020	Wind energy generation systems – Part 27-2: Electrical simulation models – Model validation
IEC 60034-4-1:2018	Rotating electrical machines – Part 4-1: Methods for determining electrically excited synchronous machine quantities from tests
IEC 61400-50-3:2022	Wind energy generation systems – Part 50-3: Use of nacelle-mounted lidars for wind measurements

3.5 Solar Energy

3.5.1 Resources

Kenya's solar irradiance on a horizontal plane is 4.5 kWh/m^2per day, translating to an annual figure of 1642.50 kWh/m^2. According to IRENA, by the end of 2019, Kenya's total installed capacity stood at 95 MW. Thus, solar forms a significant percentage of the renewable energy mix and is the most widespread. Kenya has excellent solar potential, with the western and northern parts having much higher electricity potential than the eastern side of the country.

The energy potential countrywide is estimated at 15,000 MW. This provides sufficient energy to power the country in terms of solar thermal and electricity.

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3.5.2 Solar PV Standards

3.5.2.1 Solar PV adopted or adapted in Kenya

Solar PV is one of RETs with the greatest number of local standards, with 60 of them adopted or adapted.

Table 10: Solar PV standards adopted or adapted in Kenya

Reference	Title
ISO 9060:2018	Solar energy — Specification and classification of instruments for measuring hemispherical solar and direct solar radiation
ISO 9845-1:1992	Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5
ISO 9846:1993	Solar energy — Calibration of a pyranometer using a pyrheliometer
ISO/TR 9901:2021	Solar energy — Pyranometers — Recommended practice for use
IEC 60904-1:2020	Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics
IEC 60904-1-1:2017	Photovoltaic devices – Part 1-1: Measurement of current-voltage characteristics of multi-junction photovoltaic (PV) devices
IEC 60904-2:2015	Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices
IEC 60904-5:2011	Photovoltaic devices – Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method
IEC 60904-8:2014	Photovoltaic devices – Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device
IEC 60904-9:2020	Photovoltaic devices – Part 9: Classification of solar simulator characteristics
IEC 61215-1:2021	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements
IEC 61215-1-1:2021	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules
IEC 61215-1-2:2021+AMD1:2022 CSV	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-2: Special requirements for testing of thin-film Cadmium Telluride (CdTe) based photovoltaic (PV) modules
IEC 61215-1-3:2021+AMD1:2022 CSV	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-3: Special requirements for testing of thin-film amorphous silicon-based photovoltaic (PV) modules
IEC 61215-1-4:2021+AMD1:2022 CSV	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1-4: Special requirements for testing of thin-film Cu(In, Ga)(S, Se)2 based photovoltaic (PV) modules
IEC 61215-2:2021	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures
IEC 61683:1999	Photovoltaic systems – Power conditioners – Procedure for measuring efficiency
IEC 61724-1:2021	Photovoltaic system performance – Part 1: Monitoring
IEC TS 61724-2:2016	Photovoltaic system performance – Part 2: Capacity evaluation method
IEC TS 61724-3:2016	Photovoltaic system performance – Part 3: Energy evaluation method
IEC 61727:2004	Photovoltaic (PV) systems – Characteristics of the utility interface

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Reference	Title
IEC 61730-1:2016	Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction
IEC 61730-2:2016	Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing
IEC 61829:2015	Photovoltaic (PV) array – On-site measurement of current-voltage characteristics
IEC TS 61836:2016	Solar photovoltaic energy systems – Terms, definitions and symbols
IEC 62109-1:2010	Safety of power converters for use in photovoltaic power systems – Part 1: General requirements
IEC 62109-2:2011	Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters
IEC 62109-3:2020	Safety of power converters for use in photovoltaic power systems – Part 3: Particular requirements for electronic devices in combination with photovoltaic elements
IEC 62116:2014	Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures
IEC 62124:2004	Photovoltaic (PV) stand-alone systems – Design verification
IEC 62253:2011	Photovoltaic pumping systems – Design qualification and performance measurements
IEC TS 62257-1:2015	Recommendations for renewable energy and hybrid systems for rural electrification – Part 1: General introduction to IEC 62257 series and rural electrification
IEC TS 62257-2:2015	Recommendations for renewable energy and hybrid systems for rural electrification – Part 2: From requirements to a range of electrification systems
IEC TS 62257-3:2015	Recommendations for renewable energy and hybrid systems for rural electrification – Part 3: Project development and management
IEC TS 62257-4:2015	Recommendations for renewable energy and hybrid systems for rural electrification – Part 4: System selection and design
IEC TS 62257-5:2015	Recommendations for renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards
IEC TS 62257-6:2015	Recommendations for renewable energy and hybrid systems for rural electrification – Part 6: Acceptance, operation, maintenance and replacement
IEC TS 62257-7:2017	Recommendations for renewable energy and hybrid systems for rural electrification – Part 7: Generators
IEC TS 62257-7-3:2018	Recommendations for renewable energy and hybrid systems for rural electrification – Part 7-3: Generator set – Selection of generator sets for rural electrification systems
IEC TS 62257-9-1:2016	Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-1: Integrated systems – Micropower systems
IEC TS 62257-9-2:2016	Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-2: Integrated systems – Microgrids
IEC TS 62257-9-3:2016	Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-3: Integrated systems – User interface
IEC TS 62257-9-4:2016	Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-4: Integrated systems – User installation

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Reference	Title
IEC TS 62257-9-5:2018	Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-5: Integrated systems – Laboratory evaluation of stand-alone renewable energy products for rural electrification
IEC TS 62257-9-6:2019	Renewable energy and hybrid systems for rural electrification – Part 9-6: Integrated systems – Recommendations for selection of Photovoltaic Individual Electrification Systems (PV-IES)
IEC TS 62257-9-8:2020	Renewable energy and hybrid systems for rural electrification – Part 9-8: Integrated systems – Requirements for stand-alone renewable energy products with power ratings less than or equal to 350 W
IEC 62509:2010	Battery charge controllers for photovoltaic systems – Performance and functioning
IEC 62548:2016	Photovoltaic (PV) arrays – Design requirements
IEC TS 62738:2018	Ground-mounted photovoltaic power plants – Design guidelines and recommendations
IEC 62790:2020	Junction boxes for photovoltaic modules – Safety requirements and tests
IEC 62852:2014+AMD1:2020 CSV	Connectors for DC-application in photovoltaic systems – Safety requirements and tests
IEC 62894:2014+AMD1:2016 CSV	Photovoltaic inverters – Data sheet and name plate
IEC 62930:2017	Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC

3.5.3 Gaps in the solar PV standards

While Kenya has a higher number of adopted and adapted standards, solar PV is also one of the few RETs with a larger number of standards that have not been adopted or adapted, with a total of 70 standards not having been done so (Table 11).

Table 11: Gaps in Solar PV standards

Reference	Title
ISO 9847:1992	Solar energy — Calibration of field pyranometers by comparison to a reference pyranometer
IEC TS 60904-1-2:2019	Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices
IEC 60904-3:2019	Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data
IEC 60904-4:2019	Photovoltaic devices – Part 4: Photovoltaic reference devices – Procedures for establishing calibration traceability
IEC 60904-7:2019	Photovoltaic devices – Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices
IEC 60904-8-1:2017	Photovoltaic devices – Part 8-1: Measurement of spectral responsivity of multi-junction photovoltaic (PV) devices

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Reference	Title
IEC 60904-10:2020	Photovoltaic devices – Part 10: Methods of linear dependence and linearity measurements
IEC TS 60904-13:2018	Photovoltaic devices – Part 13: Electroluminescence of photovoltaic modules
IEC TR 60904-14:2020	Photovoltaic devices – Part 14: Guidelines for production line measurements of single-junction PV module maximum power output and reporting at standard test conditions
IEC 61701:2020	Photovoltaic (PV) modules – Salt mist corrosion testing
IEC 61853-1:2011	Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating
IEC 61853-2:2016	Photovoltaic (PV) module performance testing and energy rating – Part 2: Spectral responsivity, incidence angle and module operating temperature measurements
IEC 61853-3:2018	Photovoltaic (PV) module performance testing and energy rating – Part 3: Energy rating of PV modules
IEC 61853-4:2018	Photovoltaic (PV) module performance testing and energy rating – Part 4: Standard reference climatic profiles
IEC 62093:2022	Photovoltaic system power conversion equipment – Design qualification and type approval
IEC 62108:2022	Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval
IEC TS 62257-7-1:2010	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic generators
IEC TS 62257-7-2:2022	Recommendations for renewable energy and hybrid systems for rural electrification – Part 7-2: Generator set – Off-grid wind turbines
IEC TS 62257-7-4:2019	Recommendations for renewable energy and hybrid systems for rural electrification – Part 7-4: Generators – Integration of solar with other forms of power generation within hybrid power systems
IEC TS 62257-8-1:2018	Recommendations for renewable energy and hybrid systems for rural electrification – Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems – Specific case of automotive flooded lead-acid batteries available in developing countries
IEC TS 62257-9-7:2019	Renewable energy and hybrid systems for rural electrification – Part 9-7: Recommendations for selection of inverters
IEC PAS 62257-10:2017	Recommendations for renewable energy and hybrid systems for rural electrification – Part 10: Silicon solar module visual inspection guide
IEC TS 62257-12-1:2020	Recommendations for renewable energy and hybrid systems for rural electrification – Part 12-1: Laboratory evaluation of lamps and lighting appliances for off-grid electricity systems
IEC 62446-1:2016+AMD1:2018 CSV	Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid-connected systems – Documentation, commissioning tests and inspection

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Reference	Title
IEC 62446-2:2020	Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 2: Grid-connected systems – Maintenance of PV systems
IEC TS 62446-3:2017	Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 3: Photovoltaic modules and plants – Outdoor infrared thermography
IEC 62670-1:2013	Photovoltaic concentrators (CPV) – Performance testing – Part 1: Standard conditions
IEC 62670-2:2015	Photovoltaic concentrators (CPV) – Performance testing – Part 2: Energy measurement
IEC 62670-3:2017	Photovoltaic concentrators (CPV) – Performance testing – Part 3: Performance measurements and power rating
IEC 62688:2017	Concentrator photovoltaic (CPV) modules and assemblies – Safety qualification
IEC 62716:2013	Photovoltaic (PV) modules – Ammonia corrosion testing
IEC 62759-1:2022	Photovoltaic (PV) modules – Transportation testing – Part 1: Transportation and shipping of module package units
IEC TS 62782:2016	Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing
IEC 62787:2021	Concentrator photovoltaic (CPV) solar cells and cell on the carrier (CoC) assemblies – Qualification
IEC 62788-1-2:2016	Measurement procedures for materials used in photovoltaic modules – Part 1-2: Encapsulants – Measurement of volume resistivity of photovoltaic encapsulants and other polymeric materials
IEC 62788-1-4:2016+AMD1:2020 CSV	Measurement procedures for materials used in photovoltaic modules – Part 1-4: Encapsulants – Measurement of optical transmittance and calculation of the solar-weighted photon transmittance, yellowness index, and UV cut-off wavelength
IEC 62788-1-4:2016	Measurement procedures for materials used in photovoltaic modules – Part 1-4: Encapsulants – Measurement of optical transmittance and calculation of the solar-weighted photon transmittance, yellowness index, and UV cut-off wavelength
IEC 62788-1-5:2016	Measurement procedures for materials used in photovoltaic modules – Part 1-5: Encapsulants – Measurement of change in linear dimensions of sheet encapsulation material resulting from applied thermal conditions
IEC 62788-1-6:2017+AMD1:2020 CSV	Measurement procedures for materials used in photovoltaic modules – Part 1-6: Encapsulants – Test methods for determining the degree of cure in Ethylene-Vinyl Acetate
IEC 62788-1-6:2017	Measurement procedures for materials used in photovoltaic modules – Part 1-6: Encapsulants – Test methods for determining the degree of cure in Ethylene-Vinyl Acetate
IEC 62788-1-7:2020	Measurement procedures for materials used in photovoltaic modules – Part 1-7: Encapsulants – Test procedure of optical durability
IEC TS 62788-2:2017	Measurement procedures for materials used in photovoltaic modules – Part 2: Polymeric materials – Front sheets and back sheets

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Reference	Title
IEC 62788-5-1:2020+AMD1:2022 CSV	Measurement procedures for materials used in photovoltaic modules – Part 5-1: Edge seals – Suggested test methods for use with edge seal materials
IEC 62788-5-1:2020	Measurement procedures for materials used in photovoltaic modules – Part 5-1: Edge seals – Suggested test methods for use with edge seal materials
IEC TS 62788-5-2:2020	Measurement procedures for materials used in photovoltaic modules – Part 5-2: Edge seals – Durability evaluation guideline
IEC 62788-6-2:2020	Measurement procedures for materials used in photovoltaic modules – Part 6-2: General tests – Moisture permeation testing of polymeric materials
IEC TS 62788-7-2:2017	Measurement procedures for materials used in photovoltaic modules – Part 7-2: Environmental exposures – Accelerated weathering tests of polymeric materials
IEC 62788-7-3:2022	Measurement procedures for materials used in photovoltaic modules – Part 7-3: Accelerated stress tests – Methods of abrasion of PV module external surfaces
IEC TS 62789:2014	Photovoltaic concentrator cell documentation
IEC TS 62804-1:2015	Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon
IEC TS 62804-1-1:2020	Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1-1: Crystalline silicon – Delamination
IEC TS 62804-2:2022	Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 2: Thin-film
IEC 62805-1:2017	Method for measuring photovoltaic (PV) glass – Part 1: Measurement of total haze and spectral distribution of haze
IEC 62805-2:2017	Method for measuring photovoltaic (PV) glass – Part 2: Measurement of transmittance and reflectance
IEC 62817:2014+AMD1:2017 CSV	Photovoltaic systems – Design qualification of solar trackers
IEC 62817:2014	Photovoltaic systems – Design qualification of solar trackers
IEC 62891:2020	Maximum power point tracking efficiency of grid-connected photovoltaic inverters
IEC 62892:2019	Extended thermal cycling of PV modules – Test procedure
IEC TS 62910:2020	Utility-interconnected photovoltaic inverters – Test procedure for under-voltage ride-through measurements
IEC TS 62915:2018	Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting
IEC TS 62916:2017	Photovoltaic modules – Bypass diode electrostatic discharge susceptibility testing
IEC 62920:2017+AMD1:2021 CSV	Photovoltaic power generating systems – EMC requirements and test methods for power conversion equipment
IEC 62925:2016	Concentrator photovoltaic (CPV) modules – Thermal cycling test to differentiate increased thermal fatigue durability
IEC 62938:2020	Photovoltaic (PV) modules – Non-uniform snow load testing

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Reference	Title
IEC 62941:2019	Terrestrial photovoltaic (PV) modules – Quality system for PV module manufacturing
IEC 62979:2017	Photovoltaic modules – Bypass diode – Thermal runaway test
IEC TS 62989:2018	Primary optics for concentrator photovoltaic systems
IEC TS 62994:2019	Photovoltaic (PV) modules through the life cycle – Environmental health and safety (EH&S) risk assessment – General principles and nomenclature
IEC TS 63019:2019	Photovoltaic power systems (PVPS) – Information model for availability
IEC TS 63049:2017	Terrestrial photovoltaic (PV) systems – Guidelines for effective quality assurance in PV systems installation, operation and maintenance
IEC 63092-1:2020	Photovoltaics in buildings – Part 1: Requirements for building-integrated photovoltaic modules
IEC 63092-2:2020	Photovoltaics in buildings – Part 2: Requirements for building-integrated photovoltaic systems
IEC TS 63106-1:2020	Simulators used for testing of photovoltaic power conversion equipment – Recommendations – Part 1: AC power simulators
IEC TS 63106-2:2022	Simulators used for testing of photovoltaic power conversion equipment – Recommendations – Part 2: DC power simulators
IEC TS 63109:2022	Photovoltaic (PV) modules and cells – Measurement of diode ideality factor by quantitative analysis of electroluminescence images
IEC 63112:2021	Photovoltaic (PV) arrays – Earth fault protection equipment – Safety and safety-related functionality
IEC TS 63126:2020	Guidelines for qualifying PV modules, components and materials for operation at high temperatures
IEC TS 63140:2021	Photovoltaic (PV) modules – Partial shade endurance testing for monolithically integrated products
IEC TR 63149:2018	Land usage of photovoltaic (PV) farms – Mathematical models and calculation examples
IEC TS 63156:2021	Photovoltaic systems – Power conversion equipment performance – Energy evaluation method
IEC TS 63157:2019	Photovoltaic systems – Guidelines for effective quality assurance of power conversion equipment
IEC TS 63163:2021	Terrestrial photovoltaic (PV) modules for consumer products – Design qualification and type approval
IEC 63202-1:2019	Photovoltaic cells – Part 1: Measurement of light-induced degradation of crystalline silicon photovoltaic cells
IEC TS 63202-2:2021	Photovoltaic cells – Part 2: Electroluminescence imaging of crystalline silicon solar cells
IEC TS 63202-4:2022	Photovoltaic cells – Part 4: Measurement of light and elevated temperature-induced degradation of crystalline silicon photovoltaic cells
IEC TS 63209-1:2021	Photovoltaic modules – Extended-stress testing – Part 1: Modules
IEC TS 63217:2021	Utility-interconnected photovoltaic inverters – Test procedure for over-voltage ride-through measurements

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Reference	Title
IEC TR 63225:2019	Incompatibility of connectors for DC-application in photovoltaic systems
IEC TR 63226:2021	Managing fire risk related to photovoltaic (PV) systems in buildings
IEC TR 63227:2020	Lightning and surge voltage protection for photovoltaic (PV) power supply systems
IEC TR 63228:2019	Measurement protocols for photovoltaic devices based on organic, dye-sensitized or perovskite materials
IEC TS 63265:2022	Photovoltaic power systems – Reliability practices for operation
IEC TR 63279:2020	Derisking photovoltaic modules – Sequential and combined accelerated stress testing
IEC TR 63292:2020	Photovoltaic power systems (PVPSs) – Roadmap for robust reliability
IEC TS 63342:2022	C-Si photovoltaic (PV) modules – Light and elevated temperature induced degradation (LETID) test – Detection
IEC TS 63349-2:2022	Photovoltaic direct-driven appliance controllers – Part 2: Operation modes and graphic display

3.5.4 Summary of gaps in solar PV systems

The main gaps for solar PV are in design, installation, operation and maintenance standards in addition to battery storage systems (Table 12).

Table 12: Adoption/adaptation Gaps in the standards for Solar PV

References	Title	Gap
KS 1673-1:2004	Solar photovoltaic power systems — Design, installation, operation, monitoring and maintenance — Code of practice — Part 1: General PV system requirements	The Code of Practice (CoP) was developed in 2004, and an analysis of the document indicates that it is no longer suitable for today's market needs. Specifically: • The standard only covers systems up to 12-kilo watts peak (kWp) which is not reflective of the range of capacity of systems installed in the country; • The scope of the standard is not clear whether it covers grid-connected systems • The CoP is voluminous and thus not user-friendly; • The CoP is prescriptive with preference given to crystalline PV modules, a departure from good standardisation practices; KS 1673-1:2004 should be revised and replaced with two proposed documents: • Stand-alone solar photovoltaic systems — Code of Practice; and • Grid-connected solar photovoltaic systems — Code of Practice.
KS 1709-4:2009	Batteries for use in photovoltaic power systems – Specification Part 4: Recommended practice for sizing lead acid batteries for photovoltaic (PV) systems.	The sizing should include the lifetime of service of the battery which will incorporate the servicing of the battery e.g. travel to the site to add/top up water for the open / vented lead acid batteries. The role of a PV charge controller to minimise water loss and hence reduce top-up water once or twice a year needs to be emphasised Different steps in the battery charging procedure need to be incorporated in detail viz:

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References	Title	Gap
		The main charge, used for charging the battery up to a voltage level when gassing starts and the voltage rises. (The voltage limit is 2.39 V at 25°C and 2.33 V at 40°C). Top-up charge, to reach the 100 % state of charge from a level of 90 – 95 %. (Retain the voltage limit by decreasing the current). Equalisation charge, used for equalising the capacity of the individual cells, in a multicell battery. This is an important issue for improving life but requires a special controller mode to create this in a system charged by PV panels. (Increase the voltage to 2.5 – 2.6 V/cell for a short time, 0.5 – 1 h, at regular intervals, once a week). Maintenance charge, used for maintaining the full capacity of a battery that is already fully charged but not frequently used for some period. (Approx. 2.20 – 2.25 V/cell or a current value equal to the capacity value divided by 100 (C/100)). For valve regulated or sealed battery due to their special nature, it requires special (lower) voltage settings in the controller during charging
IEC/EN 60086-1	standardize primary batteries concerning dimensions, nomenclature, terminal configurations, markings, test methods, performance, safety and environmental aspects	A need to adopt this standard and include the following: Charge control including regular equalisation mode Charge control with battery temperature compensation – Battery state of charge display for the user (LCD or LED) – Discharge control with the low state of charge warning and disconnect Protection against lightning and wrong polarity. Overcurrent protection (built-in fuse for example)
IEC 62133 IEC 62619 UL 1642 UL 2580 UN/DOT 38.3	Safety Test Standard of Li-Ion Cell and Battery Covers the safety standards for secondary lithium cells and batteries, and specifies the requirements for the safe application of LIBs in electronics and other industrial applications. UL standard for safety for lithium batteries provides standard requirements for primary and secondary lithium battery cells used as a power source in electronic products. UL standard for safety for batteries for use in electric vehicles Also called T1-T8 Tests and UN ST/SG/AC.10/11/Rev. 5	Not currently adopted or adapted in Kenya Commercial emphasis needs to be given to the battery lifetime estimation of the PV-Battery or other RET-Battery systems to enhance manufacturing, installation, operation and maintenance of batteries especially lithium-ion phosphate ($LiFEPO_4$) batteries which are an upcoming technology. Such battery lifetime estimation models should be tested and compared to enable ease of adoption by various value chain actors based on their capability and technical proficiency. These models include: For lead acid batteries Equivalent full cycles models Rain flow cycle count model Weighted Ah throughput model For $LiFEPO_4$ batteries Equivalent full cycles model Cycle ageing model

3.6 Solar thermal Standards

3.6.1 Solar thermal standards adopted or adapted in Kenya

Only a few solar thermal standards have been adopted or adapted in Kenya.

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Table 13: Solar thermal adopted or adapted in Kenya

Reference	Title
KS 1890:2009	Solar heating systems for domestic hot water – Design, installation, repair and maintenance – Code of practice
KS 1852-1:2009	Thermal solar systems and components – Factory-made systems – Part 1: General requirements.
KS 1852-2:2009	Thermal solar systems and components – Factory-made systems – Part 2: Test methods.
KS 1872:2009	Standard practice for non-operational exposure and inspection of a solar collector.
KS ISO 9459-1:1993	Solar heating – Domestic water heating systems – Part 1: Performance rating procedure using indoor test methods.
KS ISO 9845-1:1992	Solar energy – Reference solar spectral irradiance at the ground at different receiving conditions – Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5.
KS IEC 60730-2-8:2018 + AMD	Automatic electrical controls Part 2-8: Particular requirements for electrically operated water valves, including mechanical requirements
KS IEC60730-2-7:2015	Automatic electrical controls for household and similar use – Part 2-7: Particular requirements for timers and time switches.
KS 1869:2009	Determination of solar reflectance near ambient temperature using a portable solar reflectometer – Test method
KS 1871:2009	Determining resistance of solar collector covers to hail by impact with propelled ice balls – Test method.
KS 1891:2009	Evaluating absorptive solar receiver materials when exposed to conditions simulating stagnation in solar collectors with cover plates – Test method.
KS 1870:2009	Exposure of solar collector cover materials to natural weathering under conditions simulating stagnation mode – Test method.
KS 1890:2009	Installation and service of solar space heating systems for one- and two- family dwellings – Code of practice.
KS 1860:2009	Solar heating systems for domestic hot water – Design, installation, repair and maintenance – Code of practice.
KS 1895:2009	Solar heating systems for swimming pools – Code of practice.
KS 1898:2009	A standard method for on-site inspection and verification of the operation of solar domestic hot water systems.
KS 1873:2009	Standard practice for exposure of cover materials for solar collectors to natural weathering under conditions simulating operational mode.
KS 1872:2009	Standard practice for non-operational exposure and inspection of a solar collector.
KS 1892:2009	Standard practice for generating all-day thermal performance data for solar collectors.
KS 1855-1:2009	Thermal solar systems and components – Custom built systems – Part 1: General requirements.
KS 1855-2:2009	Thermal solar systems and components – Custom built systems – Part 2: Test method.
KS 1855-3:2009	Thermal solar systems and components – Custom built systems – Part 3: Performance characterization of stores for solar heating systems.
KS 1852-1:2009	Thermal solar systems and components – Factory-made systems – Part 1: General requirements.
KS 1852-2:2009	Thermal solar systems and components – Factory-made systems – Part 2: Test methods.

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Reference	Title
KS 1851-1:2009	Thermal solar systems and components – Solar collectors – Part 1: General requirements.
KS 1851-2:2009	Thermal solar systems and components – Solar collectors – Part 2: Test methods.
ISO 9553:1997	Solar energy — Methods of testing preformed rubber seals and sealing compounds used in collectors
ISO 9806:2017	Solar energy — Solar thermal collectors — Test methods
ISO 9808:1990	Solar water heaters — Elastomeric materials for absorbers, connecting pipes and fittings — Method of assessment
ISO/TR 10217:1989	Solar energy — Water heating systems — Guide to material selection about internal corrosion
ISO 9459-1:1993	Solar heating — Domestic water heating systems — Part 1: Performance rating procedure using indoor test methods
ISO 9459-2:1995	Solar heating — Domestic water heating systems — Part 2: Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems
ISO 9459-5:2007	Solar heating — Domestic water heating systems — Part 5: System performance characterization using whole-system tests and computer simulation

3.6.2 Solar thermal standards gaps

The main gaps for solar thermal address collector components and test methods. At its most foundational level is the need to adopt universally accepted definitions with respect to solar energy, specifically solar thermal. This is provided by the newest ISO 9488:2022 standards. Subsequently, there is a need to consider various aspects of solar thermal collectors, like test methods for seals (ISO 9553:1997) and collector assessment methods and tests (ISO 9808:1990 and ISO 9806:2017). Other aspects of collectors and the solar water heater system include corrosion (ISO/TR 10217:1989), component durability and performance (ISO 22975-1:2016, ISO 22975-2:2016, ISO 22975-3:2014, and ISO 22975-5:2019), and lastly, solar thermal collector sizing (IEC 62862-5-2:2022). These are detailed in Table 14:

Table 14: Solar thermal Standards not adopted or adapted

Reference	Title
ISO 9488:2022	Solar energy — Vocabulary
ISO 9553:1997	Solar energy — Methods of testing preformed rubber seals and sealing compounds used in collectors
ISO 9806:2017	Solar energy — Solar thermal collectors — Test methods
ISO 9808:1990	Solar water heaters — Elastomeric materials for absorbers, connecting pipes and fittings — Method of assessment
ISO/TR 10217:1989	Solar energy — Water heating systems — Guide to material selection with regard to internal corrosion
ISO 22975-1:2016	Solar energy — Collector components and materials — Part 1: Evacuated tubes — Durability and performance
ISO 22975-2:2016	Solar energy — Collector components and materials — Part 2: Heat-pipes for solar thermal application — Durability and performance
ISO 22975-3:2014	Solar energy — Collector components and materials — Part 3: Absorber surface durability

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Reference	Title
ISO 22975-5:2019	Solar energy — Collector components and materials — Part 5: Insulation material durability and performance
IEC 62862-5-2:2022	Solar thermal electric plants - Part 5-2: Systems and components - General requirements and test methods for large-size linear Fresnel collectors
ISO 9488:2022	Solar energy — Vocabulary Kenya has adopted the 1999 version
ISO 22975-1:2016	Solar energy — Collector components and materials — Part 1: Evacuated tubes — Durability and performance
ISO 22975-2:2016	Solar energy — Collector components and materials — Part 2: Heat-pipes for solar thermal application — Durability and performance
ISO 22975-3:2014	Solar energy — Collector components and materials — Part 3: Absorber surface durability
ISO 22975-5:2019	Solar energy — Collector components and materials — Part 5: Insulation material durability and performance
ISO 9459-4:2013	Solar heating — Domestic water heating systems — Part 4: System performance characterization utilizing component tests and computer simulation
ISO 24194:2022	Solar energy — Collector fields — Check of performance
ISO 9059:1990	Solar energy — Calibration of field pyrheliometers by comparison to a reference pyrheliometer

3.7 Bio-energy

Bioenergy includes several technologies that are either quasi-renewable (wood and wood waste, briquettes, biodiesel, bioethanol, biomass gasification) or fully renewable (biogas, landfill gases, bio-slurry).

3.7.1 Biogas

3.7.1.1 Resource assessment

Technically, biogas potential exists in 35 of the 46 districts in Kenya. The highest potential areas are Nyanza's western and central provinces, specifically Kakamega, Kiambu, Kisii, Nakuru, and Nyandarua counties. The Rift Valley and Eastern Provinces also have a limited scope.

3.7.1.2 Biogas Standards adopted or adapted

These include the following (Table 15)

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Table 15: Standards adapted or adopted in Kenya for biogas

References	Title
KS 2520:2014	Domestic biogas stoves- Specification
KS 2521:2014	Domestic biogas lamps — Specification
KS 2566-1: 2015	Design and construction of domestic biogas plants Code of practice Part 1: General
KS 2566-2: 2015	Design and construction of domestic biogas plants- Code of practice Part 2: Fixed dome
KS 2566-3: 2015	Design and construction of domestic biogas plants- Code of practice Part 3: Floating drum.
KS 2584: 2015	Biogas- Glossary, abbreviations and fundamental principles.
KS 2951:2022	Biogas systems- Code of practice for farm and industrial scale biogas systems

There is no international technical standard for biogas injection into the grid, but some countries have developed national standards and procedures for biogas injection.

3.7.2 Gaps in the Bio-gas standards

i. No standards have been developed in Kenya that are specifically meant for tubular (plastic or membrane) biogas systems.
ii. Discussions and the potential development of standards addressing the composition and characterization of feedstock for methane, particularly lignocellulosic agricultural waste and grasses (like elephant grass), need to be developed.
iii. Standards addressing the utilisation of biogas systems in the treatment of human sewage systems: this type of system should be considered different from biogas systems utilising agricultural or animal wastes or even municipal or urban solid wastes.
iv. Group or association standards to support government-based standards
v. Standards on the utilisation of biogas (commercialization) and digestate

3.7.3 Case studies for national level Bio-gas standards

3.7.3.1 Utilization of group/association for Bio-gas standards development

China presents a very unique case of the use of groups or associations to support the development of biogas standards. In Kenya, civil society organisations particularly NGOs, have previously supported the development of standards. Examples of such include SNV and practical Action.

The use of groups or associations tends to have a much bigger representation from both users and producers. Thus, their inputs tend to be much more cross-cutting and detailed. This could lead to the development of standards covering various feedstocks (Table 16).

Table 16: Biogas standards developed by groups and associations

Standard No.	Standard Name
CECS 339:2013	Technical Specifications for heating biogas reactor by ground source heat pump

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Standard No.	Standard Name
T/JSNYXH 001-2017	Construction and operation standards of large and medium straw biogas engineering
T/BGLM 0003.03-2017	Technical Code for bio-natural gas production- membrane separation technology
T/BGLM 0003.02-2017	Technical code for bio-natural gas production- Water scrubbing technology
T/BGLM 0003.01-2017	Methods for bio-natural gas testing
T/JSNYXH 001-2018	Construction and operation standards of large and medium straw biogas engineering
T/JSNYXH 0003.01-2018	Quality requirements for bio-natural gas entering natural gas pipes networks
T/BGLM 0004.01-2018	Bio-natural Gas
T/CAQI 60-2018	Biological treatment for sewage and wastewater high-loading internal circulation anaerobic reactor
T/BGLM 0001.02-2019	Evaluation of domestic garbage biodegradability: Estimation of Biogas production from Biodegradable organic matter
T.BGLM 0001.02-2019	Evaluation of domestic garbage biodegradability: Determination of biogas production by fermentation experiment
T/CECS 654-2019	Technical specification for purification of engineering bio-natural gas

(Wang et al., 2020)

3.7.4 Standards for domestic sewage treatment using Bio-gas digesters

i. The standards cover the digester design, drawings and construction
ii. It also covers the operation and maintenance and quality standards of the BDDST
iii. The effluent from the digestor is something that the standards should also cover – In China, this is covered by the digestate standards (Table 17)

Table 17: Standards on Bio-gas systems treating domestic sewage

Standard No.	Standard Name
NY/T 1702-2009	Technology specifications of Biogas digester for domestic sewage treatment
NY/T 2597-2014	Collection of standard design drawings of Biogas digester for domestic sewage treatment
NY/T 2601-2014	Construction regulations of biogas digester for domestic sewage treatment
NY/T 2602-2014	O&M specification of biogas digester for domestic sewage treatment
NY/T 3440-2019	Quality acceptance of biogas digester for domestic sewage treatment

(Wang et al., 2020)

3.7.5 Biogas standards for digestate / bio-slurry

i. The digestate can be in liquid or solid form.
ii. Solid form can be applied as fertilizer, while liquid form can be used as an insect repellent, liquid fertilizer or in hydroponics
iii. Gaps for standards exist (Table 18) in its use as insect repellents and use as liquid fertilizer or in hydroponics

Table 18: Biogas standards for digestate

Standard No.	Standard Name
NY/T 1917-2010	Mobile discharge facilities for digested sludge and slurry
NY/T 1916-2010	Fixed discharge facilities for digested sludge and slurry

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Standard No.	Standard Name
NY/T 2065-2011	Technical Code for application of anaerobic digestate fertilizer
NY/T 2139-2012	Processing equipment of anaerobically digested fertilizer
NY/T 2374-2013	Technical code for post-treatment of digested sludge and slurry from Biogas plant
NY/T 2596-2014	Anaerobic digested fertilizer
NY/T 2855-2015	Test method of mobile discharge facilities for digested sludge and slurry
NY/T 2856-2015	Test method of fixed discharge facilities for digested sludge and slurry
NB/T 10071-2018	Technical code for onsite management of digested sludge and slurry from liquid biofuel by-products

(Wang et al., 2020)

Biogas standards should look into the commercialization aspects of the biogas system.

i. Key areas of commercialization include commercial packaging and containerization of biogas, affordable use of local materials in the cleaning of biogas, and lastly, productive use of biogas.
ii. Experimental standardisation should be emphasised. This refers to employing research, experiments, and innovation to feed into standard development.

3.8 Bio-syngas

Biogas can be obtained from anaerobic fermentation but can also be obtained by thermal processes resulting in a mixture containing hydrogen, carbon dioxide, and other gases to obtain bio-syngas, or producer gas, through a process of gasification or pyrolysis of biomass.

Generally, gasification is an incomplete combustion promoted by an oxidising (gasifying) agent to produce Carbon dioxide, steam, hydrogen, and low amounts of methane. This combination of gases is called producer or syngas. The calorific value varies depending on the gasifying agent utilised (Table 19).

Table 19: Syngas from various biomass based on gasifying agent

Gasifying agent	%-v (dry basis) H2	O	CO2	CH4	N2	Gasification Technology	Reference
AIR	12-20	17-22	9-15	50-54	50-54	downdraft	(Gunarathne, 2012)
Air	7-9	13-17	18-21	3	50-59	Bubbling fluidized bed	(Lahijani & Zainal, 2011)
Oxygen	23	36	28	5	7	Entrained flow	(Kremling et al., 2017)
Steam/Oxygen	30-33	22-27	28-32	9-11	<2	ICBFB ENEA	(Barisano et al., 2012)
Steam/Oxygen	30-31	17-19	34-35	7	8-10	Circulating fluidized bed	(Kurkela et al., 2016)
Steam	36-42	19-24	20-25	12-Sep	-	DFB	(Pfeifer et al., 2011)

3.8.1 Bio-syngas adopted and adapted Standards

In assessing the standards currently adopted or adapted in Kenya we were unable to get any. Internationally, there are no direct technical IEC / ISO standards addressing bio-syngas.

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Table 20: Bio-syngas standards related to or under development

References	Title
KS ISO/IEC 13273-2:2015	Energy efficiency and renewable energy sources — Common international terminology — Part 2: Renewable energy sources

3.8.2 Gaps in Bio-syngas standards:

International standards not adopted/adapted to Kenya (Table 21)

Table 21: Bio-syngas standards related to or under development

References	Title
ISO/TR 21916:2021	Solid recovered fuels — Guidance for the specification of solid recovered fuels (SRF) for selected uses
DD CEN/TS 15439:2006	Biomass gasification. Tar and particles in product gases. Sampling and analysis
ISO 13577-2:2014	Industrial furnaces and associated processing equipment — Safety — Part 2: Combustion and fuel handling systems
ISO/AWI 23898 [under development]	Gasification systems for bio-syngas and biomethane production

3.8.3 Capacity assessment of Bio-syngas

Businesses at this stage are involved in the development, manufacture and production of bioenergy equipment including the underlying conversion processes. The competencies required for these levels of production include:

i. Science and engineering competencies to develop the equipment and processes
ii. Occupations in relation to manufacture
iii. Marketing and sales occupation

In Kenya, the development of gasifiers apart from major companies and organizations is mainly confined to the research stage. Local manufacture is thus quite limited.

3.9 Improved cookstoves

3.9.1 Cookstove characterization and quantification

Cook stoves make a huge portion of the energy mix in terms of utilised technologies. In studies done by the Ministry of Energy and Petroleum, the main stove categories and brands were identified as shown in Table 22

Table 22: Characterisation and quantification of cookstoves in Kenya

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Type of cook stove	Cookstove description	Examples of current market stoves	Manufacturers or distributors	Number of households using it
Branded Woodstoves	Manufactured Wood stoves Biomass gasifier	Kuni Okoa, Jiko Dura"24cm", Jiko Dura "28 cm", Model 2-M2, SmartSaver Wood, SuperSaver wood, Kuni mbili	Burn, EcoZoom, Envirofit, Wisdom, SCODE	54,000
Branded Charcoal stoves	Manufactured charcoal stoves	Jikokoa, Jiko Bora, Jiko Fresh, SuperSaver Charcoal, SmartSaver Charcoal	BURN, EcoZoom, Envirofit, Wisdom	386,000
Non-branded woodstoves	Fixed biomass stoves Kuni mbili stoves	Artisans / jua kali sector	Artisans / Jua kali sector	1,400,000 270,000
Non-branded Charcoal stoves	Kenya Ceramic Jiko Metallic charcoal stoves	Artisans / jua kali sector	Artisans / Jua kali sector	4,200,000 1,200,000
LPG Stoves	Meko (single burner) LPG stove (multiple burner	Total, Kobil, Pro-gas, K-gas, Hashi, Afrigas, Oil Libya, Lake Gas, Mid Gas e.t.c	Total, Kobil, Oil Libya, Pro-gas	3,700,000
Kerosene stoves	Kerosene wick stove Pressurized kerosene stove	Parameko, Fire wheel Brand Kerosene Wick Stove, Generic Handy Portable 8 Wicks Kerosene Stove	Gundua Engineering Services	1,400,000
	Electric coil stove Electric induction stove Microwave Mixed LPG-Electricity stove	LG, Samsung, Ramtons, Hotpoint, Beko, Ariston, Mika Bruhms, Armco	Ramtons, Aniston, Hotpoint,	350,000
Bioethanol cookstoves	Gel bioethanol stoves Liquid Bioethanol stoves	Single or double burner cookstoves	Koko networks	600,000
Biogas cookstoves	Single or double burner cookstoves	Biogas cook stoves	Flexi Biogas International Sisteme.bio African Biogas program	40,000
Other	Solar cooker	Fireless cookers Solar Cookers	Consumer Choice,	50,000

(Kenya, 2019)

As at 2019, Kenya had 12.2 million households, with 60.67% living in urban and peri-urban areas. From Table 22

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Table 22: The higher number of total stoves over the national households count is due to the fuel and stove stacking. This is a case where families have a primary cookstove and a secondary or tertiary stove. This is quite evident in certain counties in Kenya as compared to others (Fig 6)

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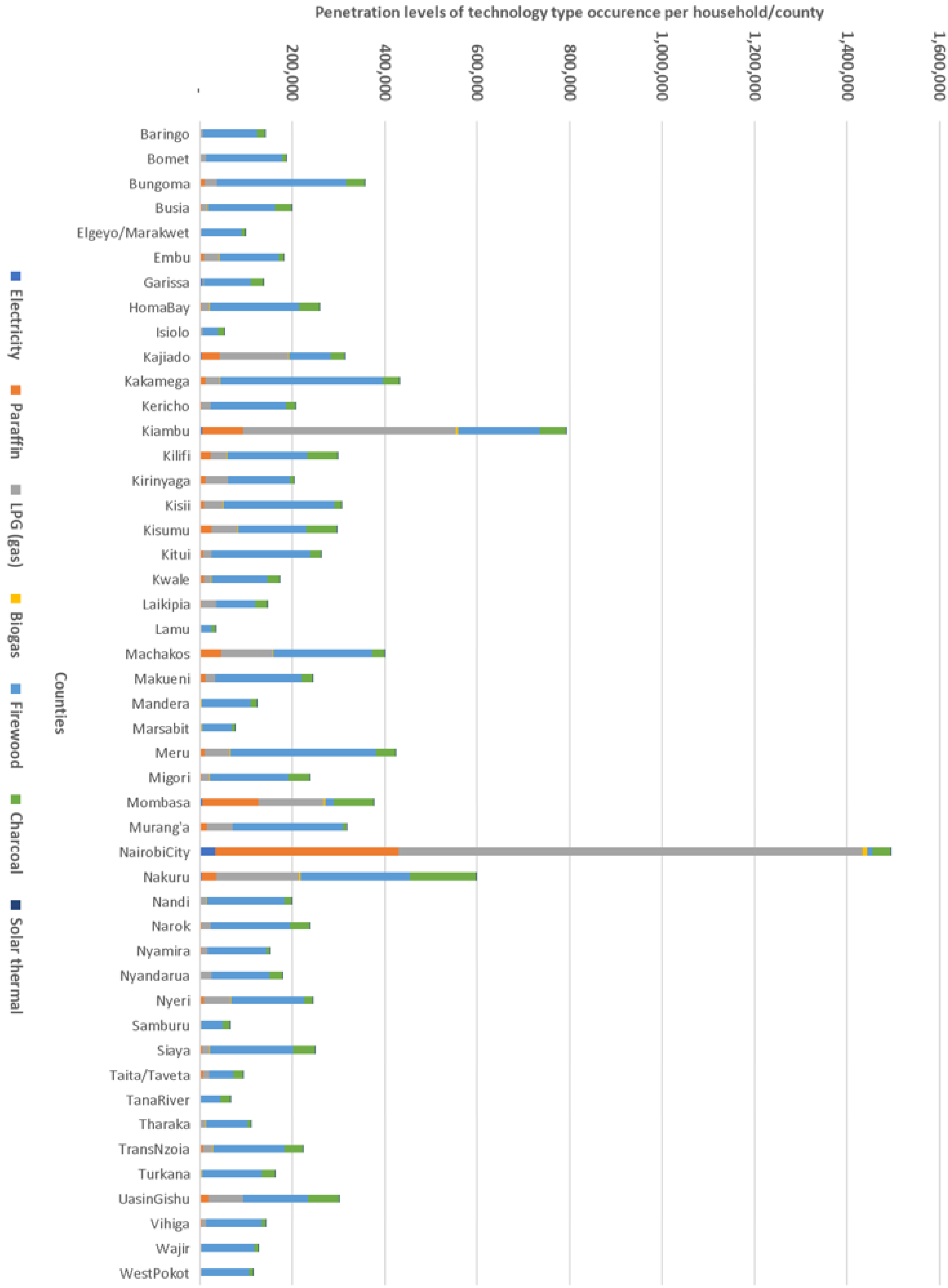

Fig 6: Different cookstoves utilisation across various Kenyan counties

In improving access to the various cooking technologies, there is a need to move from tier 1 to tier 3, then 4, and ultimately tier 5. This is a strategic progression since 2 out of every 3 households live in an urban or peri-urban area. Various households will, based on the stacking of fuel and cookstove technologies, straddle between various tiers. For instance, have a primary

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technology in tier 3 and another in tier 4, while others will straddle tiers 4 and 5. The tiers are indicated in Fig. 7.

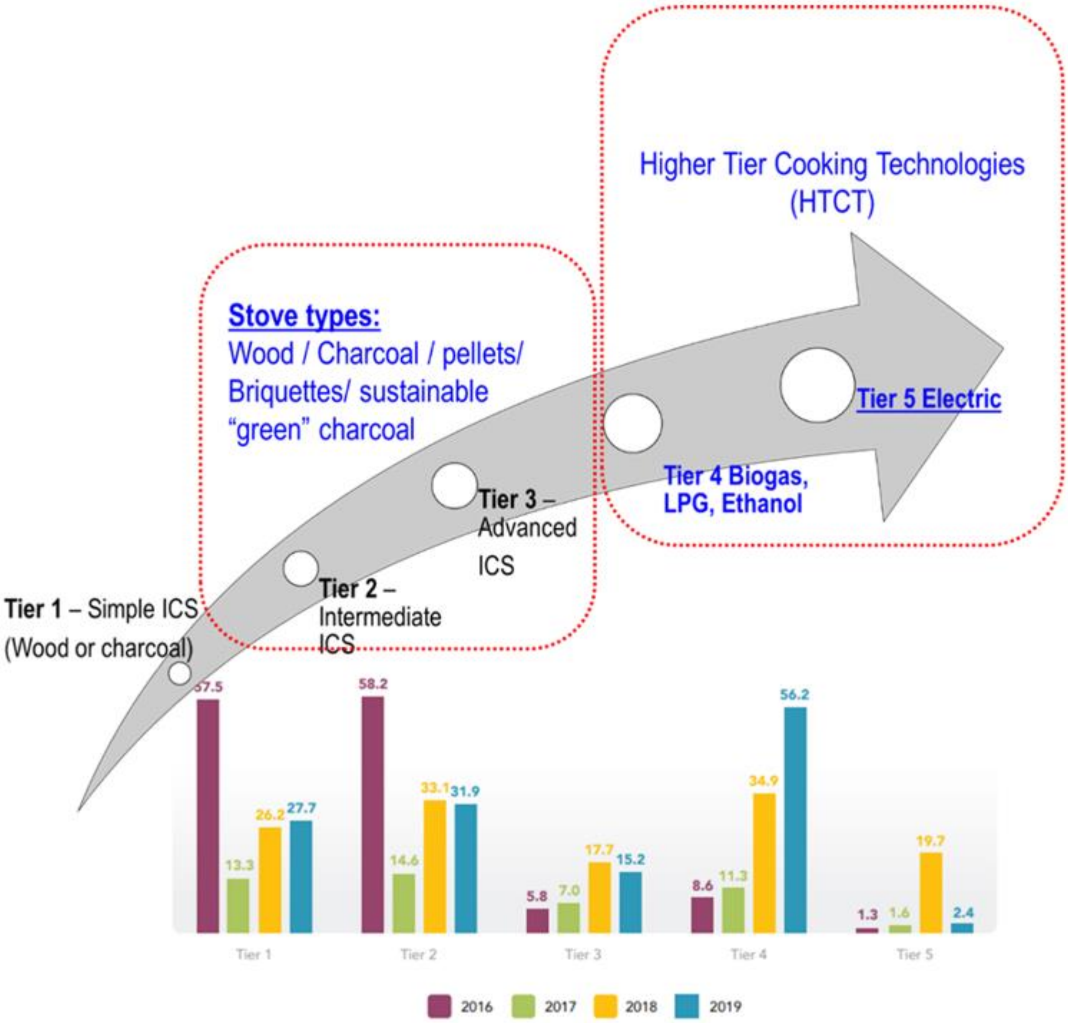

Fig 7: Cooking tiers in Kenya

3.9.2 Bio-mass fuels and cookstoves standards adopted or adapted in Kenya

Table 23: Bio-mass fuels and standards adopted or adapted in Kenya

Reference	Title
ISO 17225-1:2021	Solid biofuels — Fuel specifications and classes — Part 1: General requirements
ISO 17225-2:2021	Solid biofuels — Fuel specifications and classes — Part 2: Graded wood pellets
ISO 17225-3:2021	Solid biofuels — Fuel specifications and classes — Part 3: Graded wood briquettes
ISO 17225-4:2021	Solid biofuels — Fuel specifications and classes — Part 4: Graded wood chips
ISO 17225-5:2021	Solid biofuels — Fuel specifications and classes — Part 5: Graded firewood
ISO 17225-6:2021	Solid biofuels — Fuel specifications and classes — Part 6: Graded non-woody pellets
ISO 17225-7:2021	Solid biofuels — Fuel specifications and classes — Part 7: Graded non-woody briquettes

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Reference	Title
KS ISO 19867-1:2018	Clean cookstoves and clean cooking solutions-Harmonized laboratory test protocols-Part 1: Standard test sequence for emissions and performance, safety and durability
KS 1814:2019	Biomass stoves-Performance requirements
KS 2033:2007	Performance of handles and handle assemblies attached to cookware - Specification.
KS 1064:2000	Specification for non-pressure stoves (Second Edition). Covers the requirements for the capillary- fed, multi-wick type, non-pressure kerosene stoves
KS 1128:1995	Specification for wicks for non-pressure stoves.

3.9.3 Gaps in the standards

Table 24: Bio-mass fuels and cookstove standards requiring adoption or adaptation in Kenya

Reference	Title
ISO 16559:2022	Solid biofuels — Vocabulary
ISO 14780:2017	Solid biofuels — Sample preparation
ISO 16948:2015	Solid biofuels — Determination of total content of carbon, hydrogen and nitrogen
ISO 16967:2015	Solid biofuels — Determination of major elements — Al, Ca, Fe, Mg, P, K, Si, Na and Ti
ISO 16968:2015	Solid biofuels — Determination of minor elements
ISO 16993:2016	Solid biofuels — Conversion of analytical results from one basis to another
ISO 16994:2016	Solid biofuels — Determination of total content of sulfur and chlorine
ISO 16995:2015	Solid biofuels — Determination of the water-soluble chloride, sodium and potassium content
ISO/TS 16996:2015	Solid biofuels — Determination of elemental composition by X-ray fluorescence
ISO TS 17225-8:2016	Solid biofuels — Fuel specifications and classes — Part 8: Graded thermally treated and densified biomass fuels
ISO 17225-9:2021	Solid biofuels — Fuel specifications and classes — Part 9: Graded hog fuel and wood chips for industrial use
ISO 17827-1:2016	Solid biofuels — Determination of particle size distribution for uncompressed fuels — Part 1: Oscillating screen method using sieves with apertures of 3,15 mm and above
ISO 17827-2:2016	Solid biofuels — Determination of particle size distribution for uncompressed fuels — Part 2: Vibrating screen method using sieves with an aperture of 3,15 mm and below
ISO 17828:2015	Solid biofuels — Determination of bulk density
ISO 17829:2015	Solid Biofuels — Determination of length and diameter of pellets
ISO 17830:2016	Solid biofuels — Particle size distribution of disintegrated pellets
ISO 17831-1:2015	Solid biofuels — Determination of mechanical durability of pellets and briquettes — Part 1: Pellets
ISO 17831-2:2015	Solid biofuels — Determination of mechanical durability of pellets and briquettes — Part 2: Briquettes
ISO 18122:2015	Solid biofuels — Determination of ash content
ISO 18123:2015	Solid biofuels — Determination of the content of volatile matter
ISO 18125:2017	Solid biofuels — Determination of calorific value
ISO 18134-1:2015	Solid biofuels — Determination of moisture content — Oven dry method — Part 1: Total moisture — Reference method
ISO 18134-2:2017	Solid biofuels — Determination of moisture content — Oven dry method — Part 2: Total moisture — Simplified method

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Reference	Title
ISO 18134-3:2015	Solid biofuels — Determination of moisture content — Oven dry method — Part 3: Moisture in the general analysis sample
ISO 18135:2017	Solid Biofuels — Sampling
ISO 18846:2016	Solid biofuels — Determination of fines content in quantities of pellets
ISO 18847:2016	Solid biofuels — Determination of particle density of pellets and briquettes
ISO 19743:2017	Solid biofuels — Determination of content of heavy extraneous materials larger than 3,15 mm
ISO 20023:2018	Solid biofuels — Safety of solid biofuel pellets — Safe handling and storage of wood pellets in residential and other small-scale applications
ISO 20024:2020	Solid biofuels — Safe handling and storage of solid biofuel pellets in commercial and industrial applications
ISO/TS 20048-1:2020	Solid biofuels — Determination of off-gassing and oxygen depletion characteristics — Part 1: Laboratory method for the determination of off-gassing and oxygen depletion using closed containers
ISO 20049-1:2020	Solid biofuels — Determination of self-heating of pelletized biofuels — Part 1: Isothermal calorimetry
ISO/TS 20049-2:2020	Solid biofuels — Determination of self-heating of pelletized biofuels — Part 2: Basket heating tests
ISO 21404:2020	Solid biofuels — Determination of ash melting behaviour
ISO/TS 21596:2021	Solid biofuels — Determination of grindability — Hardgrove type method for thermally treated biomass fuels
ISO 21945:2020	Solid biofuels — Simplified sampling method for small-scale applications
ISO 23343-1:2021	Solid biofuels — Determination of water sorption and its effect on the durability of thermally treated biomass fuels — Part 1: Pellets
ISO/TR 23437:2020	Solid biofuels — Bridging behavior of bulk biofuels
KS ISO 19867-3:2018	Clean cookstoves and clean cooking solutions — Harmonized laboratory test protocols — Part 3: Voluntary performance targets for cookstoves based on laboratory testing
ISO 19869:2019	Clean cookstoves and clean cooking solutions — Field testing methods for cookstoves
ISO/TR 21276:2018	Clean cookstoves and clean cooking solutions — Vocabulary

3.10 Battery storage and its utility

3.10.1 Standards adopted or adapted

Due to the variability of some of the renewable energy resources, like wind and Solar, the need for storage becomes key. In Kenya, the standards for battery storage are listed in Table 25.

Table 25: Battery standards adopted or adapted in Kenya

References	Title
KS ISO 18300:2016	Electrically propelled vehicles-Test specifications for lithium-ion battery systems combined with lead acid battery or capacitor.
KS IEC 62509:2010	Battery charge controllers for photovoltaic systems – Performance and functioning
KS 1864:2010	Battery chargers – Performance
KS ISO 13064-1:2012	Battery-electric mopeds and motorcycles-Performance-Part 1: Reference energy consumption and range
KS ISO 13064-2:2012	Battery-Electric mopeds and motorcycles-Performance-Part 2: Road operating characteristics.

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References	Title
KS IEC 61011-1:1989	Electric fence energizers – Part 1: Safety requirements for battery-operated electric fence energizers suitable for connection to the supply mains
KS IEC 61011-2:1990	Electric fence energizers – Part 2: Safety requirements for battery-operated electric fence energizers not for connection to the supply mains.
KS ISO/PAS16898:2012	Electrically propelled road vehicles-Dimensions and designation of secondary lithium-ion cells.
KS ISOPAS 19363:2017	Electrically propelled road vehicles-Magnetic field wireless power transfer-Safety and interoperability requirements.
KS ISO 6469-2:2018	Electrically propelled road vehicles-Safety specifications-Part 2: Vehicle operational safety means and protection against failures.
KS 1709-4:2009	Batteries for use in photovoltaic power systems – Specification Part 4: Recommended Practice for sizing lead acid batteries for photovoltaic (PV) systems.
KS 1861:2005	Electrical installation – Secondary batteries are installed in buildings.
KS 1673-2-2:2003	Generic specification for solar photovoltaic systems – Systems design, installation, operations, monitoring and maintenance – Part 2:Test procedures for main components.
KS ISO/TR 11955:2008	Hybrid-electric Road Vehicles-Guidelines for charge balance measurement.
KS IEC 61056-1:2012	Lead-acid batteries (valve-regulated types) – Part 1: General requirements, functional characteristics – Methods of the test, General purpose.
KS IEC 61056-2:2012	Lead-acid batteries (valve-regulated types) – Part 2: Dimensions, terminals and marking, General purpose.
KS 185-1:2007	Lead-acid starter batteries – Part 1: General requirements and methods of test – Specification (Fourth Edition).
KS IEC 60254-1:2005	Lead-acid traction batteries – Part 1: General requirements and methods of tests.
KS IEC 60254-2:2008	Lead-acid traction batteries – Part 2: Dimensions of cells and terminals and marking of polarity on cells.
KS IEC TR 61044:2002	Opportunity-charging of lead-acid traction batteries.
KS IEC 60086-4:2019	Primary batteries Part 4: Safety of lithium batteries
IEC 61427-1:2013	Secondary cells and batteries for renewable energy storage - General requirements and methods of test- Part 1: Photovoltaic off-grid application
IEC 61427-2:2015	Secondary cells and batteries for renewable energy storage - General requirements and methods of test- Part 2: On-grid applications

3.10.2 Gaps in the standards

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Table 26: General battery standards requiring adoption or Adaptation in Kenya

Standard Number	Title
IEC 60050	International electrotechnical vocabulary. Chapter 486: Secondary cells and batteries.
IEC 60086-2, BS	Batteries - General
ANSI C18.2M	Portable Rechargeable Cells and Batteries - General and Specifications
ANSI C18.3M	Portable Lithium Primary Cells and Batteries - General and Specifications
UL 2054	Safety of Commercial and Household Battery Packs - Testing
IEEE 1625	The standard for Rechargeable Batteries for Mobile Computers
USNEC Article 480	Storage Batteries

4.0 Recommendations and conclusion

Following the analysis, this report could be considered not only an active document to show the current state and deployment levels of standards for RETs but, more importantly, what can be done to improve the current situation. The focus is on what actions individuals, institutions, and state actors like REREC can undertake to improve the penetration levels of RETs.

The key highlights of this study have been the identification and classification of renewable energy standards and their contextualization within the National energy mix. Thus, the number of findings is determined for this study, along with the seven (7) renewable energy clusters, with the following findings and recommendations:

i. Tidal and ocean power (Marine energy) standards
ii. No standards have been adopted or adapted to the Kenyan situation.
iii. Capacity-wise, no specific Manufacturers, installers, maintainers, or operators of Tidal and Ocean power systems are practising in Kenya.
iv. This in part explains the Technical Readiness Level (TRL) and Commercial Readiness Level (CRL) of zero.

4.1 Hydropower standards

i. Eleven (11) international standards have been adopted for small hydropower systems, with an additional six (6) being adopted. Those adapted have focused on technical, electro-mechanical, safety, and environmental impact analysis. A gap exists in adopting or adapting twenty-four (24) other international standards that focus on Big hydro (>10 MW installed capacity) systems. In addition, standards addressing the digitization and hybridization of hydropower plants will need to be included.
ii. Capacity-wise, the country does not have experienced engineers and companies manufacturing and selling water turbines and related electromechanical water-driven

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generating equipment. A lot of the people employed in this sector are lowly skilled labourers during construction, while the majority of engineers are expatriates (especially for big hydro systems). During operation and maintenance, a mix of engineers and technicians is seen.

4.2 Wind Energy

i. Sixteen (16) standards addressing technology and its components (namely the IEC 61400 series) have been adopted by the country. A further thirteen (13) critically relevant standards could be considered for adoption. These address offshore wind turbines, manufacturing, and verification of wind turbine blades, towers, foundations, and nacelles. In addition, Power performance, site identification, and calibration (including wind measurement campaigns and their tools)

ii. The study does note that there are no manufacturing or installed capacities for electrical wind turbines. Capacities exist for the manufacturing of mechanical wind pumps. Efforts have also been noted by one Kenyan Company that produces small wind turbines, but sales have been reduced significantly due to performance issues.

4.3 Solar Energy Standards

i. While sixty (60) Solar PV standards have been adopted or are being adopted in Kenya, another seventy (70) are yet to be adapted or adopted. The main standards gaps for Solar PV are in the design, installation, operation, and maintenance standards, in addition to battery storage systems.

ii. Unlike Solar PV standards, only twenty-six (26) solar thermal standards have been adopted or adopted in Kenya; ten (10) standards dealing with various aspects of solar thermal collectors, like test methods for seals (ISO 9553:1997) and collector assessment methods and tests (ISO 9808:1990 and ISO 9806:2017), need to be adopted or adapted. Other standards aspects that need inclusion include corrosion (ISO/TR 10217:1989), component durability and performance (ISO 22975-1:2016, ISO 22975-2:2016, ISO 22975-3:2014, and ISO 22975-5:2019), and lastly, solar thermal collector sizing (IEC 62862-5-2:2022).

iii. A capacity analysis of the solar field (thermal and PV) indicates that, Apart from batteries and cables, most of the equipment and components are manufactured abroad. Previously, some companies like Solar World were making flat-plate solar thermal collectors, but not so much anymore. Additionally, a company in Naivasha used to assemble Solar PV modules. But they are currently only doing distributions and installations. Thus, limited manufacturing capabilities exist, with most Solar components being imported. This field is, however, one of the more advanced in terms of competencies, with the majority of installations, operations, and maintenance being done by local companies or local franchises of international companies.

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4.4 Bio-energy

4.4.1 Biogas

i. Seven (7) Biogas standards have been adapted or adopted for stoves, lamps, and for design and construction. No technical standards for the injection of biogas into the grid and tubular or membrane systems have been developed for the Kenyan scenario.
ii. Deficit Standards on feedstock type, composition, and characterization, particularly for lignocellulosic materials
iii. Standards on the utilisation of biogas on a commercialization level, particularly piped or compressed methane, as well as the digestate
iv. Standards to address domestic sewage treatment using biogas digesters
v. While no international standards exist for (a)(ii to iv), National standards in China could be considered

4.4.2 Bio-syngas

i. In assessing the standards currently developed or adopted in Kenya, none were found. Internationally, there are no direct technical IEC or ISO standards addressing bio-syngas. About five international standards on bio-syngas are available that can be utilised to this end.
ii. In Kenya, the development of gasifiers, apart from major companies and organisations, is mainly confined to the research stage. Local manufacture is thus quite limited. Consequently, most manufacture and installations are done by expatriates; however, operation and maintenance are done by locals.

4.4.3 Improved cookstoves

i. Fourteen (14) standards have been adopted or adapted to the Kenyan local conditions, while another forty-one (41) international standards could be considered for adoption or adaptation.
ii. While several standards exist for the bioenergy sector, a huge gap exists in the standards that need to be adapted or adopted. This is linked to the efforts made in developing the technology as well as in human capacity development. By and large, the employment value chain is very limited to the main installation and largely to operation and maintenance. For locally produced cook stove brands, manufacturing is also done locally; however, the majority of the branded cookstoves are either imported fully or partly complete (for assembling here) in Kenya.

Generally, a low level of awareness exists about standard implementation, which is hampered mainly by the fact that the country is a net technology importer. Further, due to a lack of awareness of the technological innovations on the global level, the development of local standards and the capacity building of competent staff (including techno-financial support for renewable energy technologies) have been significantly hampered. Finally, universities and higher educational institutions have not been central to the research and analysis of renewable energy technologies.

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5.3 Conflict of interest

The author declares no conflict of interest.

5.4 Ethical consideration

None

6.0 References

AfDB. (2021). *Assessing the Potential of Offshore Renewable Energy in Africa*.

Barisano, D., Freda, C., Nanna, F., Fanelli, E., & Villone, A. (2012). Biomass gasification and in-bed contaminants removal: Performance of iron enriched Olivine and bauxite in a process of steam/O2 gasification. *Bioresource technology*, *118*, 187-194. Provide link

EPRA. (2022). *Biannual Energy and Petroleum Statistics Report*. EPRA. https://www.epra.go.ke/downloads/new-biannual-report

Gunarathne, D. (2012). Optimization of the performance ofdown-draft biomass gasifier installedat National Engineering Research &Development (NERD) Centre ofSri Lanka. In.

Kenya, M. o. E. C. C. A. o. (2019). *Kenya Household Cooking Sector Study: Assessent of the supply and Demand of Cooking solutions at the household level*. M. o. Energy.

Kremling, M., Briesemeister, L., Gaderer, M., Fendt, S., & Spliethoff, H. (2017). Oxygen-blown entrained flow gasification of biomass: impact of fuel parameters and oxygen stoichiometric ratio. *Energy & Fuels*, *31*(4), 3949-3959.

Kurkela, E., Kurkela, M., & Hiltunen, I. (2016). Steam–oxygen gasification of forest residues and bark followed by hot gas filtration and catalytic reforming of tars: Results of an extended time test. *Fuel Processing Technology*, *141*, 148-158. https://doi.org/10.1016/j.fuproc.2015.06.005

Lahijani, P., & Zainal, Z. A. (2011). Gasification of palm empty fruit bunch in a bubbling fluidized bed: a performance and agglomeration study. *Bioresource technology*, *102*(2), 2068-2076.

Pfeifer, C., Koppatz, S., & Hofbauer, H. (2011). Steam gasification of various feedstocks at a dual fluidized bed gasifier: impacts of operation conditions and bed materials. Biomass Conv. Bioref. 1: 39–53. In.

Wako, J. N., Jacinta. (2020). Provide link

Renewable Energy Law and Regulation in Kenya. CMS.

Wang, X., Yan, R., Zhao, Y., Cheng, S., Han, Y., Yang, S., Cai, D., Mang, H.-P., & Li, Z. (2020). Biogas standard system in China. *Renewable energy*, *157*, 1265-1273. https://doi.org/10.1016/j.renene.2020.05.064

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