2018 IEEE PES GENERAL MEETING

SUSTAINABLE ENERGY SYSTEMS FOR DEVELOPING COMMUNITIES, **SESDC** WORKING GROUP

PANEL: STANDARDS FOR OFF-GRID DEVELOPING COMMUNITY APPLICATIONS

Wed Aug. 8 | 13:00 - 15:00 | Room: OC-Portland Ballroom 256

SESDC

Peter Dauenhauer – Chair
Dr. Henry Louie – Co-Chair
Dr. Joseph Mutale – Past-Chair
Nirupama Prakash Kumar – Engagement Officer
Dr Barry Rawn – Communication Officer and Secretary
Robert Nutter – Microgrids Task Force Lead

http://sites.ieee.org/pes-sesdc/

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Objective of Panel

- 1.1 billion, mostly poor, without access to electricity
- Off-grid solutions will play a major role
- Lack of standardization is major obstacle to sustainability and reduces impact of investments made
- Panelists focus:
  - Standards are being developed, main features
  - Barriers to implementation
  - Stakes for those without access
  - Collaborative efforts underway, and, now needed
  - Involvement of all stakeholders in standards process
- Goal: Facilitate networking of proponents of standards efforts, identification of any gaps, and strengthen collaboration efforts

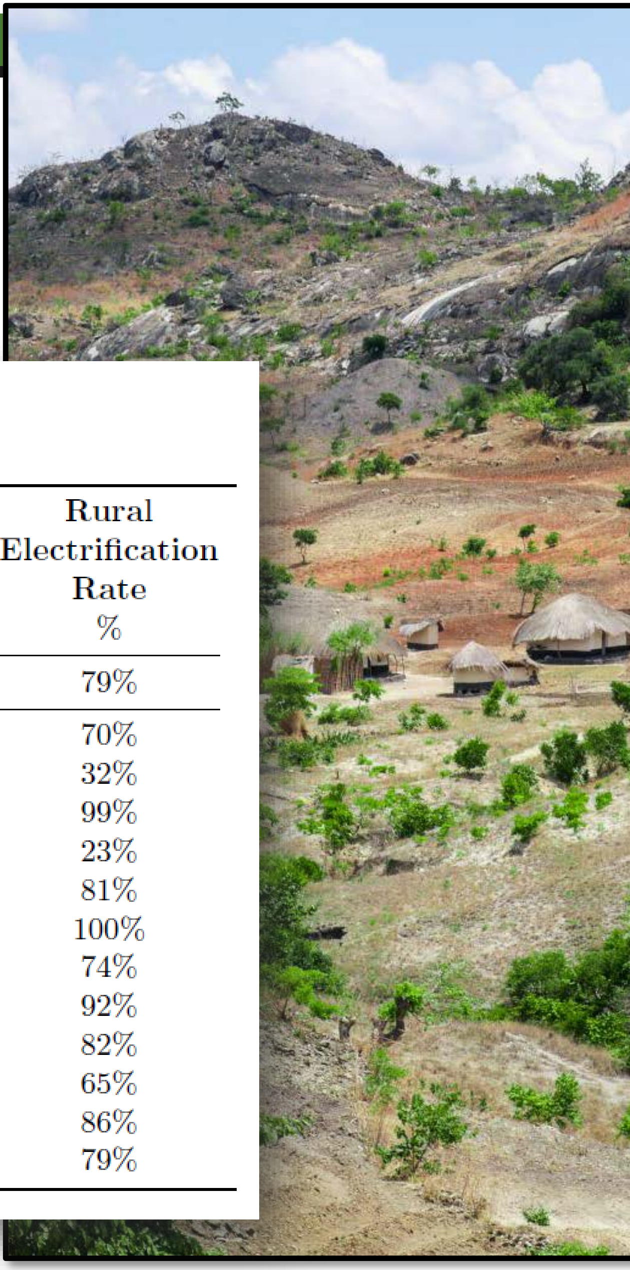
SESDC Overview

- **Raise awareness** to the technical community, governments, policymakers, and organizations about **access to energy systems**, including electricity and the related issues **in developing communities around the world**.
- Respecting social norms, traditions, and cultures, the SESDC collaborates with stakeholders to provide practical recommendations to facilitate environmentally-safe, measurable, and cost-effective **sustainable energy system technologies and solutions** to enhance economic and social viability, standard of living, and quality of life of people living in developing communities.
- Lead **practical research activities** to support the effectiveness and sustainability of electricity access efforts

Electricity Access Statistics

Table 1.1: Electricity Access in 2017, by Region

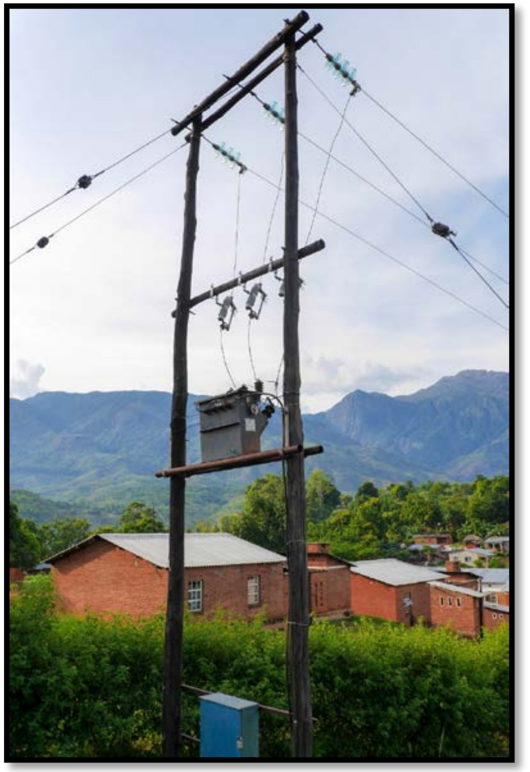
Region	Population without Electricity *millions*	Electrification Rate %	Urban Electrification Rate %	Rural Electrification Rate %
World	1,060	93%	98%	79%
Developing Countries	1,060	82%	94%	70%
Africa	588	52%	77%	32%
North Africa	< 1	99%	100%	99%
Sub-Saharan Africa	588	43%	71%	23%
Developing Asia	439	89%	97%	81%
China	-	100%	100%	100%
India	239	82%	97%	74%
Indonesia	23	91%	99%	92%
Other SE Asia	42	89%	97%	82%
Other Developing Asia	135	73%	87%	65%
Central & S. America	17	97%	98%	86%
Middle East	17	93%	98%	79%



UN SE4ALL Call to Action

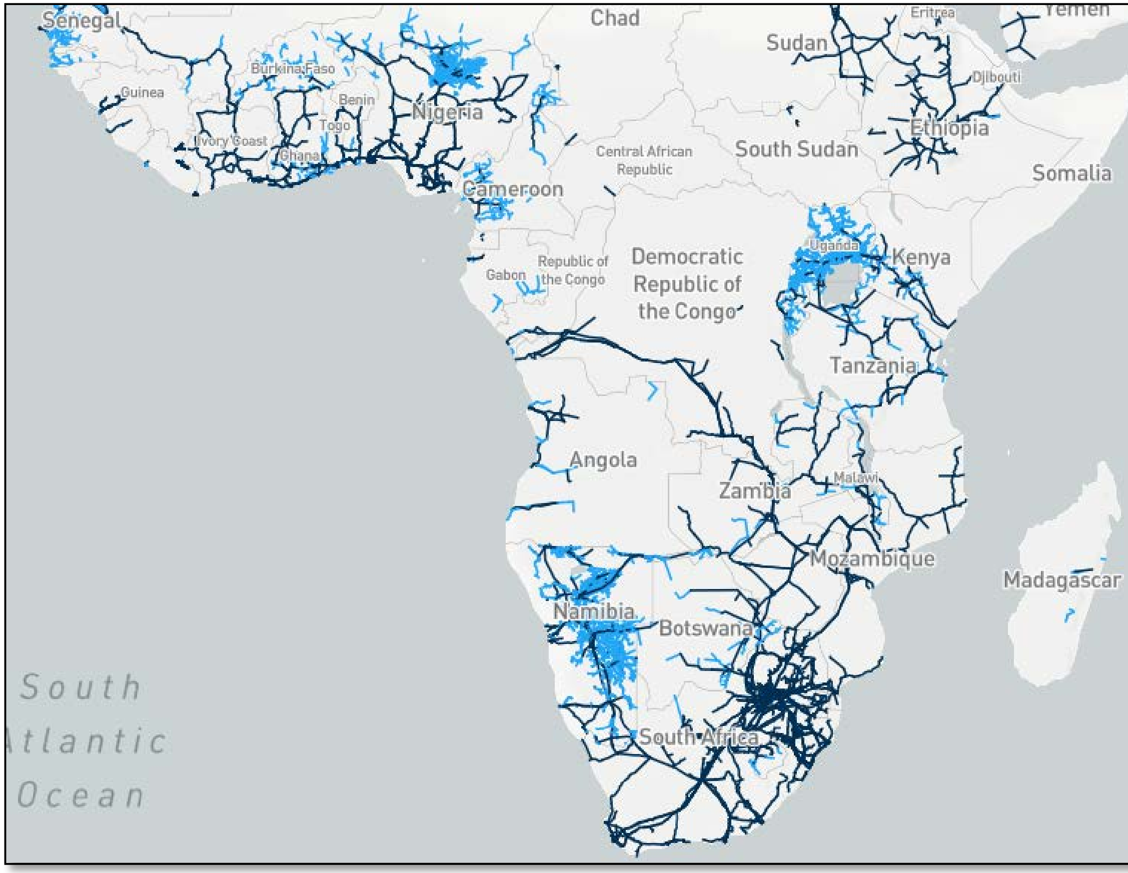
UN Sustainable Development Goals (SDG) #7, by 2030

1. Universal access to affordable, reliable and modern energy services
2. Increase share of renewable energy in the global energy mix
3. Double the global rate of improvement in energy efficiency
4. Enhance international cooperation to facilitate access to clean energy research and technology
5.Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

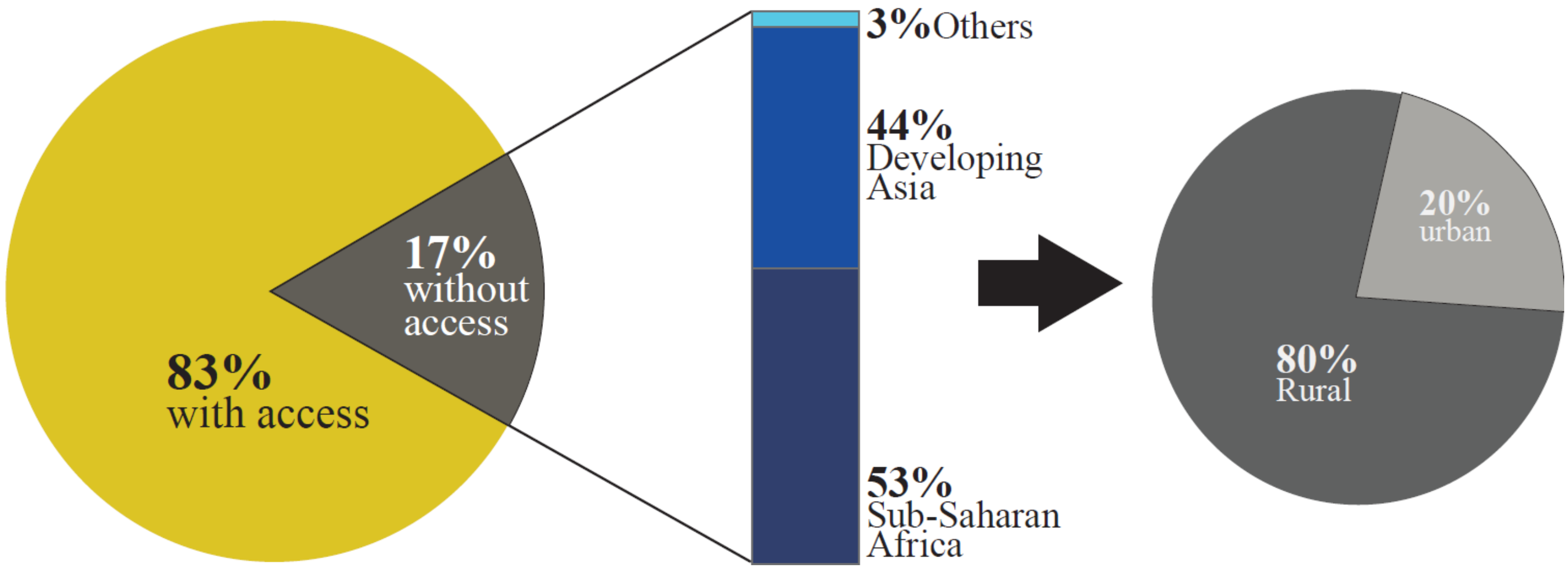


Grid Access in Developing Countries

- State-owned (or history)
- Subsidized prices
- Vertically integrated
- Dependency on external fuel supply
- High losses
- Emphasis on urban centers and key industries
- Grid-extension is loss making
- Unreliable supply - blackouts, brownouts, daily planned outages
- Extensions funded by external sources



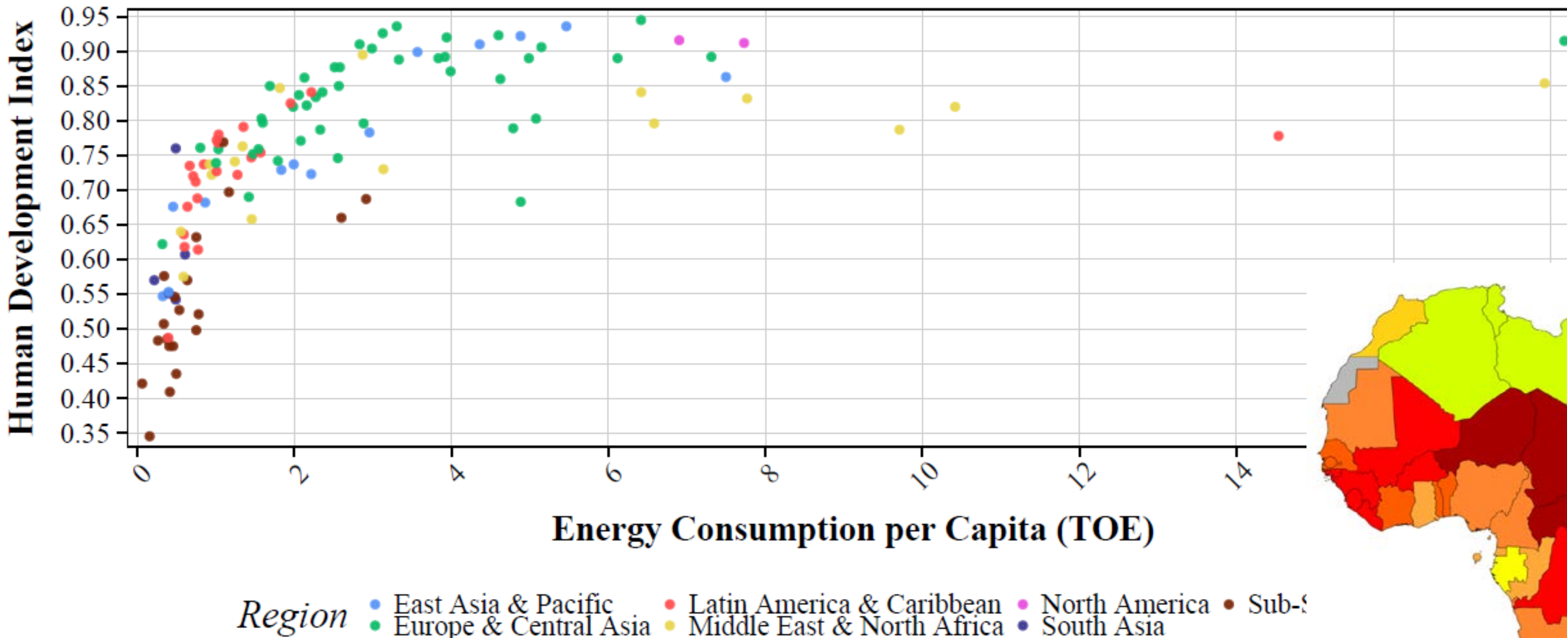
Rural v. Urban

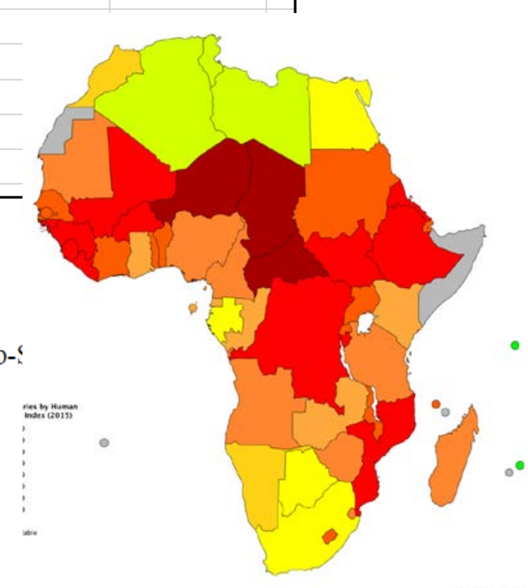


REN21, "Renewables 2016 global status report," REN21 Secretariat, 2016

Energy & Development

Figure 1.2: HDI and Energy Consumption (Per Capita, 2013)





Electrification Options

Extended Grid

Small/Medium Sized Mini-grids

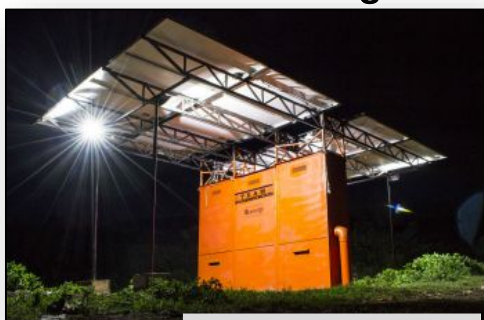


Image Source: PowerGen

Image Source: Practical Action

Pico Products

Solar Home Systems

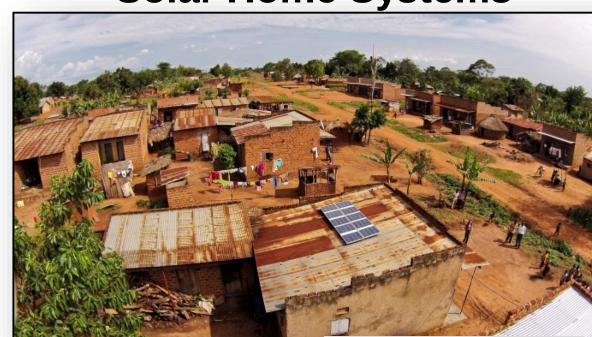


Image Source: US AID

Agenda

- Panelists' Talks (15 min each)
- Questions recorded during presentations (leave question with your Name on note)
- Open Q&A and Debate. Several selected questions will be asked first. Then open Q&A.

***Please provide questions that provoke a constructive debate**

Introduction to Talks

- **Lighting Global and Trends in the SHS market**
- **Quality Assurance Framework for Mini-grids**
- **Standardizing DC Microgrids for Rural Electrification**
- **Overview of IEC standards activities on LVDC for electricity access**
- **Opportunities of IEEE Std 1547-2018 for rural electrification with Distributed Energy Resources**

Chris Baker-Brian

- Chris Baker-Brian is the co-founder and Chief Technology Innovation Officer of BBOXX, a venture backed company developing solutions to provide affordable, clean energy to off-grid communities in the developing world. Founded in 2010 by Chris and two fellow Imperial College London students, the company has enjoyed fast growth; BBOXX has now deployed more than 150,000 solar kits and impacted over 750,000 lives across Africa and Asia. As the CTIO, Chris leads the development of a wide range of advanced rural electrification solutions, as well as a range of software products to support BBOXX's growing global operations.

Edward Ian Baring Gould

- Ian Baring-Gould graduated University of Massachusetts in 1995 and now works at the National Renewable Energy Laboratory. At NREL he focuses on applications engineering for Renewable Energy (RE) technologies, assistance in RE deployment and educational outreach, primarily wind. Relating to off grid energy systems, Ian has over 30 years of work in the minigrid market sector with a focus on integrating RE technologies and rural electrification. Ian was an early key participant in the development of IEC- 62257 Recommendations for small renewable energy and hybrid systems for rural electrification. Ian's current work centers on methodologies to expand microgrid/minigrid development through lessons from utility market development, such as the development of Quality Assurances Frameworks for minigrid power systems.

Sarah Aggrey Majok

- **Sarah Aggrey Majok** is Founder and CEO of Sarah Aggrey Consulting Engineers, a small technical advisory firm focused on transmission planning, renewable project support, and regulatory support. She has 21 years of experience in the energy industry covering transmission planning, renewable generation integration, and solar project due diligence. Sarah has conducted numerous technical studies and assessments for large electric utilities and has supported solar project developers with projects in seven countries. Previously Sarah was a renewables engineering manager at Black & Veatch, a principal transmission planning engineer at SMUD and a senior consultant at Navigant Consulting. Sarah is an IEEE Senior Member and lead for the stakeholder identification & communication task group for IEEE standard P2030.10. Sarah holds BSc and MSc degrees in Electrical and Electronic Engineering from California State University, Sacramento.

Prof. Graeme Burt

- **Graeme Burt** is a professor of electrical power systems within the Department of Electronic and Electrical Engineering at the University of Strathclyde, where he co-directs the 250 strong Institute for Energy and Environment. His research interests are in the areas of protection and control for distributed energy, electrification of propulsion, and systems-level experimental validation. Professor Burt is also the Director of the Rolls-Royce University Technology Centre (UTC) in Electrical Power Systems and Lead Academic for the Power Networks Demonstration Centre (PNDC). He is an active researcher, with a track record of leading involvement in many national and international power systems consortia research projects. Professor Burt also serves on Scotland's Aerospace, Defence, Marine and Security Industry Leadership Group, on the Steering Committee of the European Energy Research Alliance (EERA) Joint Programme in Smart Grids, and is Spokesperson for the Board of the Association of European Distributed Energy Resources Laboratories.

Dr Jens Boemer

- Jens C. Boemer is leading research on the grid integration of renewable and distributed energy resources at the Electric Power Research Institute (EPRI) where he is contributing to the drafting of IEEE and other standards, including IEEE Std 1547-2018 and other reports and white papers on interconnection requirements for DER. He received his DEng. in Electrical Engineering from Technical University of Dortmund in 2005 where he specialized on power systems and renewable energies. Jens supported the German Government in the drafting of the Ancillary Services Ordinance for wind power plants and developed an operational strategy for the Irish transmission system operator with regard to very high instantaneous shares of wind power. In 2013/2014 he worked with the Intelligent Electrical Power Grids group of the Electrical Sustainable Energy department at the Delft University of Technology for his research towards a Ph.D. degree.

Trends in the SHS Market

Christopher Baker-Brian, CTIO, BBOXX

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Overview

- The Off-Grid Challenge
- BBOXX's work in Solar Home Systems (SHS)
- Increased uptake of SHS globally
- Ongoing Challenges for the Sector

THE INITIAL PROBLEM:
A NEED FOR LIGHT

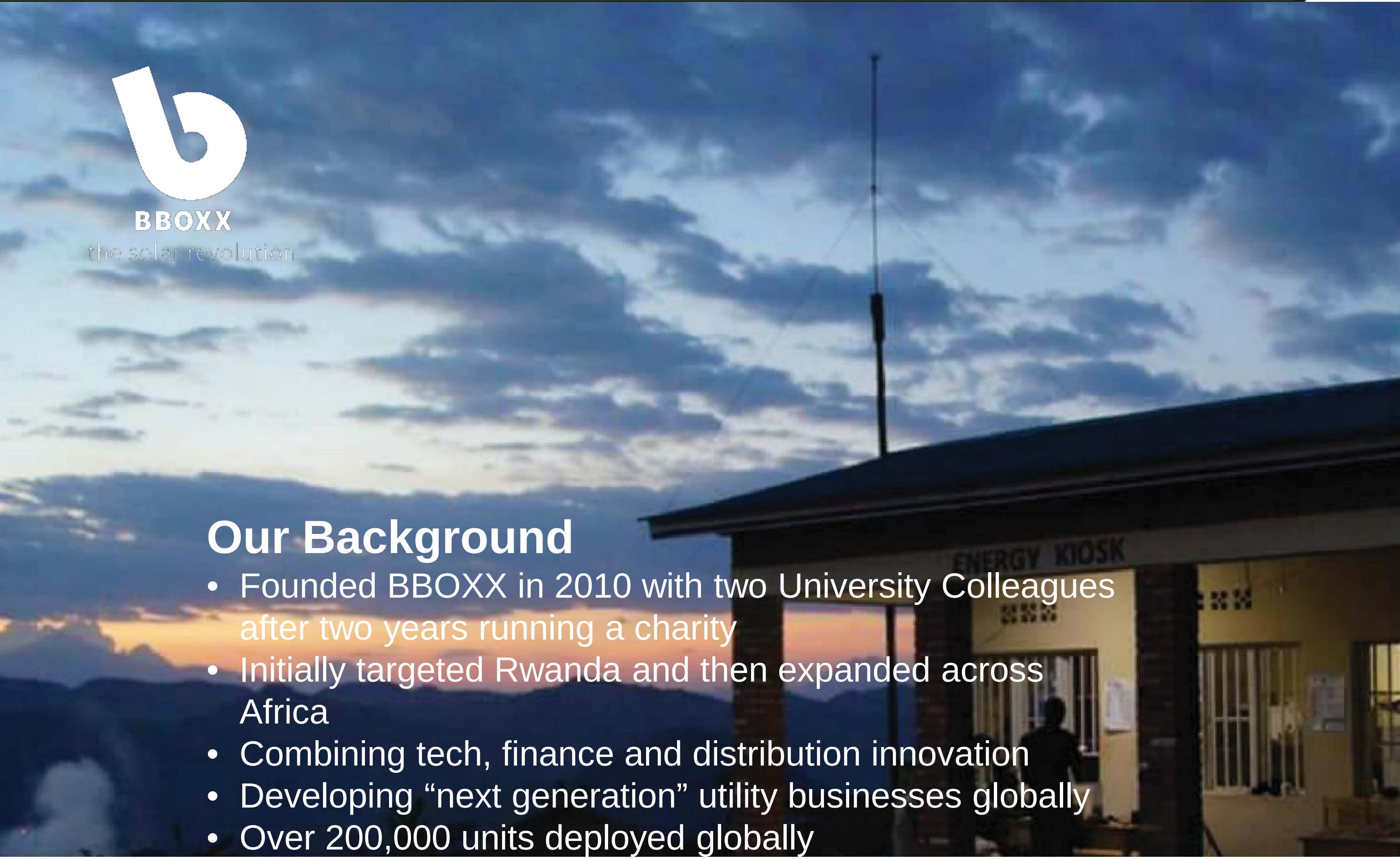
1.1 billion people live without access to electricity[1]. This is 16% of the global population[1].

53% of these people are living in Sub Saharan Africa. This equates to **632 million people**.

An additional **1 billion people** are connected to the grid but suffer from unreliable grid connections[2].

[1] Quoted from the IEA , World Energy Outlook.
[2] Quoted from GSMA Mobile for Development Report


BBOXX
the solar revolution



BBOXX
the solar revolution

Our Background

- Founded BBOXX in 2010 with two University Colleagues after two years running a charity
- Initially targeted Rwanda and then expanded across Africa
- Combining tech, finance and distribution innovation
- Developing “next generation” utility businesses globally
- Over 200,000 units deployed globally

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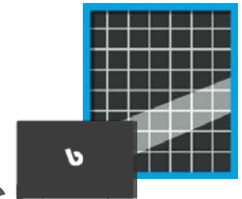
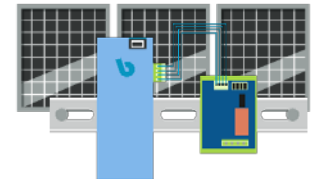
THE VIRTUAL SOLAR GRID
IS BBOXX'S ANSWER TO THE
WORLD'S ELECTRICITY SHORTAGE



BBOXX Home
50W



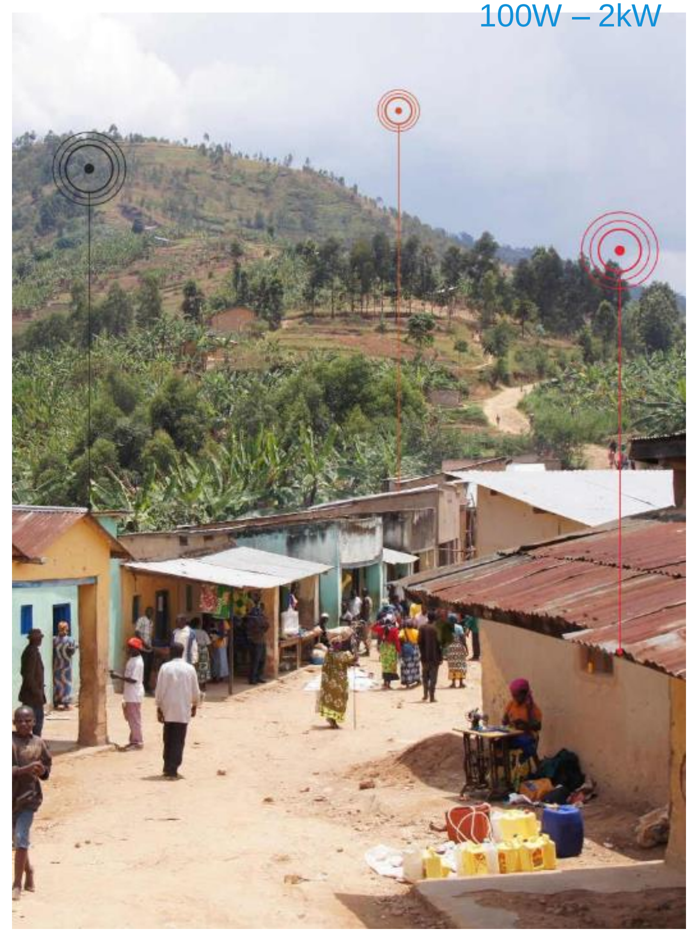
BBOXX
Enterprise
100W – 2kW

BBOXX aims to build the **largest virtual solar grid** in Africa, quickly followed by the rest of the world.

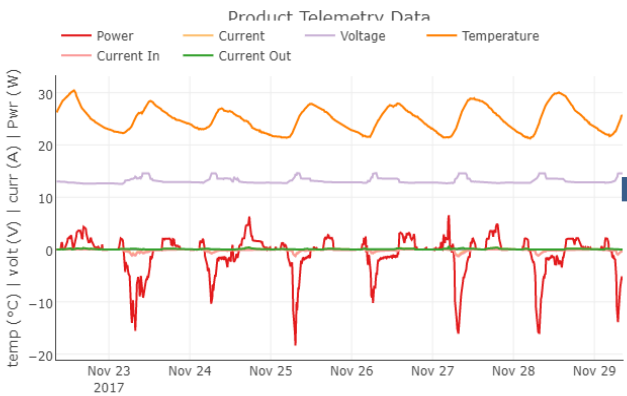
We employ a distributed grid so there are **no wires between each house.**

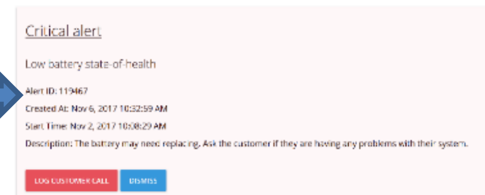
Each BBOXX unit is 'SMART' and has the capability to **send and receive data** over the mobile network.

BBOXX sells and installs the main energy storage unit in customers' homes, and then offers the additional accessories for purchase, including radios, televisions, fridges and extra lights.



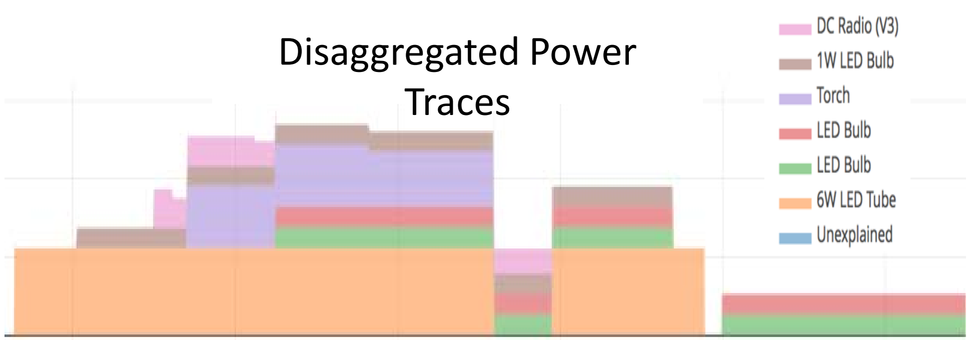
BBOXX's Pulse Platform allows data collection and automatic action generation to help manage a distributed fleet of systems

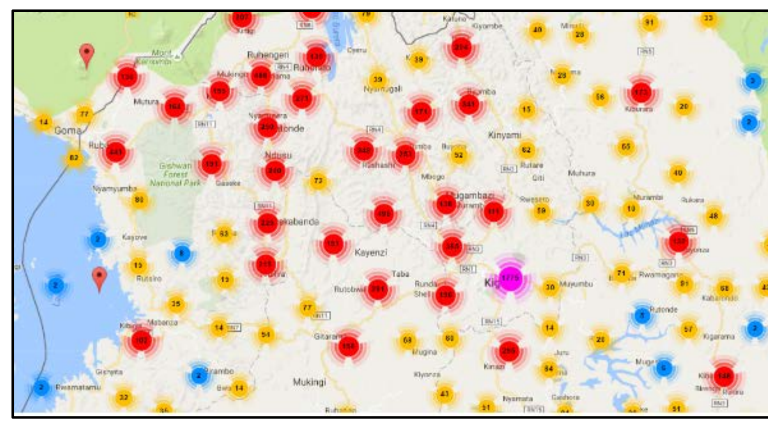




Proactive service requests improve the customer experience ("an on-grid experience in an off-grid world") and improve operational efficiency across a geographically distributed customer base

Disaggregated Power Traces





Current numbers

21,000
automated task management actions processed daily to sales, technician & call centre staff

250,000+
mobile payments processed monthly

1000+
Full and part time staff in 9 countries globally

6 MWhrs
of distributed energy monitored & controlled daily, both from SHSs and from larger installations

$65,000,000
managed customer contract value

LATEST SECTOR TRENDS AND CHALLENGES

National governments are increasingly including off-grid and decentralised energy targets in their electrification plans

CONNECTIONS

Current Access Rate: 41%
- Rural: 9% Urban: 72%

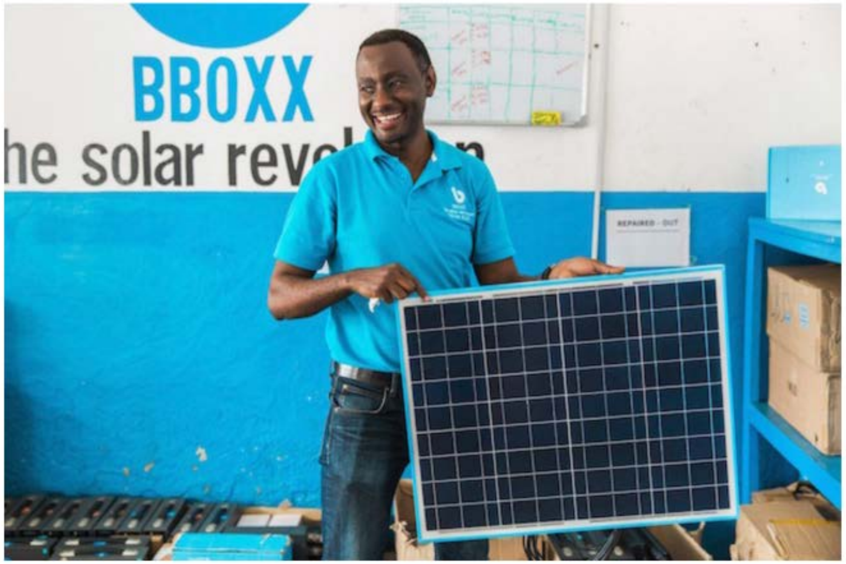
People without Power: 8 million
- Target: Universal access by 2024 (52% on-grid, 48% off-grid)

Source: Power Africa

- Traditional electrification methods struggle to deliver value fast enough with growing population
- Rwanda has a target of 48% of the population using off-grid by 2024.
- Togo has a target through its CIZO scheme to electrify 550,000 households using off-grid means by 2025.

Togo: Government reveals its ambitious new electrification strategy

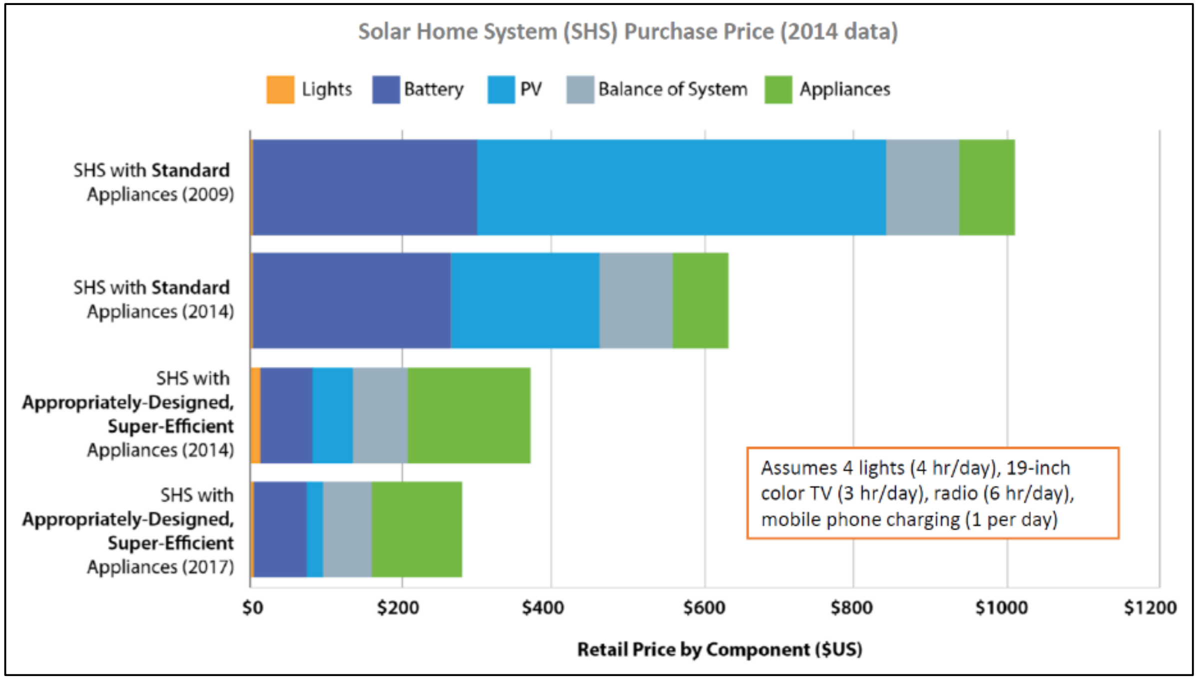
ENERGY Wednesday, 27 June 2018 17:54



(Togo First) – Togo wants to achieve 50%, 75% and 100% electrification by 2020, 2025 and 2030 respectively.

Source: https://www.togofirst.com/en/energy/2706-1119-togo-government-reveals-its-ambitious-new-electrification-strategy

Rapid reductions in SHS prices have opened up a much larger market over the last 10 years



Source: "A Home Energy System in just 25 Watts" (1.usa.gov/1K6yfyn)

- Rapid reduction in PV and Battery components has made larger SHS's more viable for consumers.
- PAYG/Energy as a Service plans have also increased the size of the addressable market
- Next sector focus is on ensuring super–efficient appliances are developed for this sector.

Lighting Global Quality Assurance program aims to reduce market spoilage and ensure consistent quality standards

LIGHTING GLOBAL

Catalyzing markets for modern off-grid lighting

Lighting Global QA Framework

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Test methods and standards

QTM

n=6

quality

IEC

Technical Specification 62257-9-5, Ed. 3.0

Testing, Verification, & Surveillance

SMQ

Shenzhen Academy of Metrology & Quality Inspection

SCHATZ ENERGY RESEARCH CENTER

Intertek

teri

ISO 17025 accredited labs for QTM testing

teri

TANZANIA BUREAU OF STANDARDS

tbs

Communicating Quality to Market

specs

www.lightingglobal.org/products

Consumer Awareness Campaigns

Stakeholder Engagement

GOGLA

Off-Grid Solar

or

DFID Department for International Development

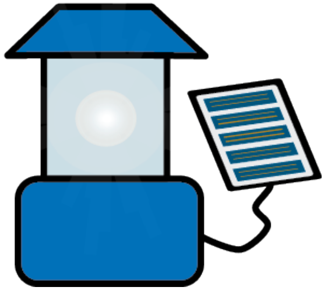
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Development Agencies

Governments

LG Test Methods and Standards exist for Pico and SHS products and over 26m quality verified units have been sold to date

Lighting Global Pico-Solar Quality Standards

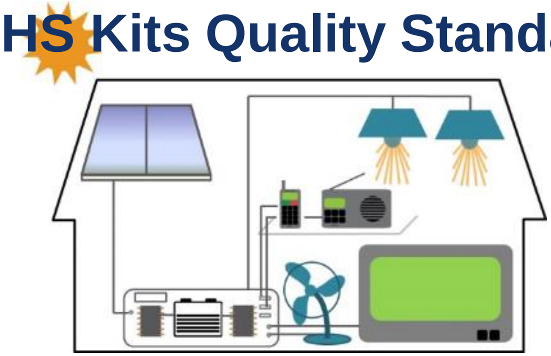


(≤ 10-15 W_p)

Table 1. Lighting Global Quality Standards

Category[a]	Metric	Quality Standard	
Truth In Advertising[b]	Manufacturer, Model # and Product Name	Accurately specified	
	Light Output and Solar Run Time	Accurately reported on packaging for the highest setting.[c] For other settings, if reported, accurately specified. If there are both pay-as-you-go (PAYG) and non-PAYG versions of a product, each must be truthfully advertised with respect to energy services provided.	
	Charger Rating	If reported, charger power rating accurately specified (e.g. PV power or mechanical charge time)	
	Lamp Type	If reported, accurately specified	
	Mobile phone charging	Impact of mobile phone charging on product performance qualitatively described on packaging[c]	
	Fee-for-service or Pay-as-you-go (PAYG) metering	The PAYG system should be capable of accurately metering service to customers so they reliably get the service that is paid for.	
	Other Aspects	If reported, accurately specified.	
Lumen Maintenance	Lumen Maintenance at 2,000 hours	Average relative light output ≥ 85% of initial light output at 2,000 hours with only one sample allowed to fall below 75% OR All 6 samples maintain ≥ 95% of initial light output at 1,000 hours.[d] If an included lighting appliance provides ≥ 15 lumens, it is subject to the lumen maintenance standard	
Health and Safety	AC-DC Charger Safety	*Any included* AC-DC charger carries approval from a recognized consumer electronics safety certification organization[e]	
	Hazardous Substances Ban	No battery may contain cadmium or mercury at levels greater than trace amounts (<0.0005% Hg and <0.002% Cd by weight in accordance with the EU Battery Directive)	
Battery	Battery Protection	Protected by an appropriate charge controller that prolongs battery life and protects the safety of the user. Five out of 6 samples must meet the requirements outlined below.[f] Batteries of included appliances must also meet this standard. For PAYG systems, appropriate battery protection must remain active regardless of whether the system is in an enabled or disabled state. To avoid damage to a battery during long-term periods of non-payment disabled system states, the solar module must be able to charge the battery even if the product is in a disabled state	
	Battery Durability	The average capacity loss of 6 samples must not exceed 25% and only one sample may have a capacity loss greater than 35% following the battery durability storage test as defined in IEC 62257-9-5 Annex BB. If an included lighting appliance provides ≥15 lumens, it is subject to the battery durability standard. All other appliances are not required to meet this standard.	
Quality and Durability[g,h]	Physical Ingress Protection (for components containing electronics or electrical connections)	*Fixed Outdoor*	IP5x
		Others	IP2x
		All PV Modules	IP3x

Lighting Global SHS Kits Quality Standards



(11 W_p - 350 W_p)

Table 1. Solar Home System Kit Quality Standards

Category[a]	Metric	Quality Standard
Truth In Advertising	Manufacturer	Accurately specified
	Product Name & Model No.	Accurately specified
	Performance Claims: Light Output, Run Time, Appliance Power Consumption	If reported, accurately specified.[b] If there are both pay-as-you-go (PAYG) and non-PAYG versions of a product, each must be truthfully advertised with respect to energy services provided.
	Lamp Type, PV Power, Battery Capacity, Charger Rating, Other Aspects	PV power must be accurately reported on the product packaging. All other aspects, if reported, must be accurately specified.[b]
	Fee-for-service or Pay-as-you-go (PAYG) metering	The PAYG system should be capable of accurately metering service to customers so they reliably get the service that is paid for.
	Ports	Port voltage and current specifications, if provided, must be accurate. Included appliances must function when connected to SHS ports. Power output of ports must be sufficient to power appliances that are advertised but not included. Specific guidelines for USB and 12 V ports are below.[c] Ports of included appliances are not required to meet this standard.
	Functionality	All advertised features must be functional. Any description of the product that appears on the packaging, inside the package and in any other medium (internet, etc.) should be truthful and accurate. No statements should mislead buyers or end users about the features or utility of the product. Any user interfaces (charge indicators, SOC estimates, etc.) must be accurate.
Lumen Maintenance	Lumen Maintenance at 2,000 Hours	Average relative light output of 4 samples ≥ 90% of initial light output at 2,000 hours with only one sample allowed to fall below 85%. OR All samples maintain ≥ 95% of light output at 1,000 hours. If an included lighting appliance provides ≥15 lumens, it is subject to the lumen maintenance standard.[d]
Health and Safety	Circuit and Overload Protection	The system must pass an overcurrent and an overload protection test. Products must include a current limiting mechanism to prevent irreversible damage to the system. The mechanism must be easily resettable or replaceable by the user, or must automatically reset. If replaceable fuses are used for circuit protection, sizes must be labeled on the device and listed in the user manual, and, if fuses are replaceable by the user, at least one spare fuse must be included with the product. Included appliances are not required to meet this standard.
	AC-DC Charger Safety	*Any included* AC-DC charger carries approval from a recognized consumer electronics safety certification organization.[e]
	Wiring and Connector Safety	Wires, cables and connectors must be appropriately sized for the expected current and voltage.[f]
	Hazardous Substances Ban	No battery may contain cadmium or mercury at levels greater than trace amounts (<0.0005% Hg and <0.002% Cd by weight in accordance with the EU Battery Directive)

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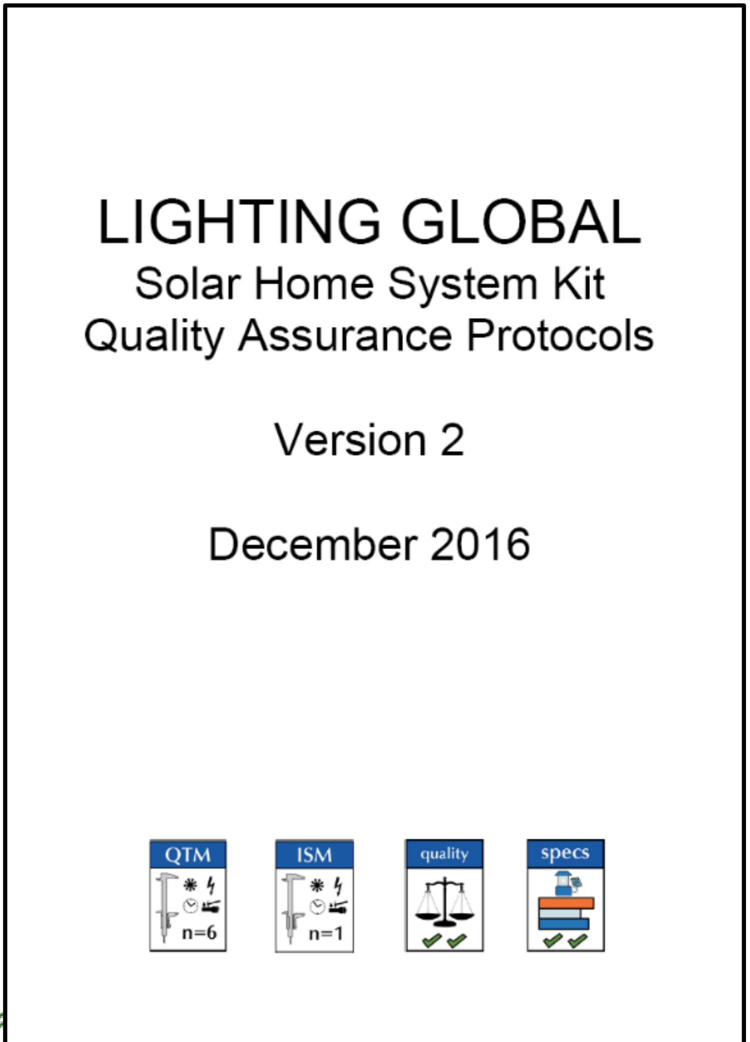
GOGLA and IEC are liaising to ensure quality standards are mainstreamed and adopted by national governments


LIGHTING GLOBAL

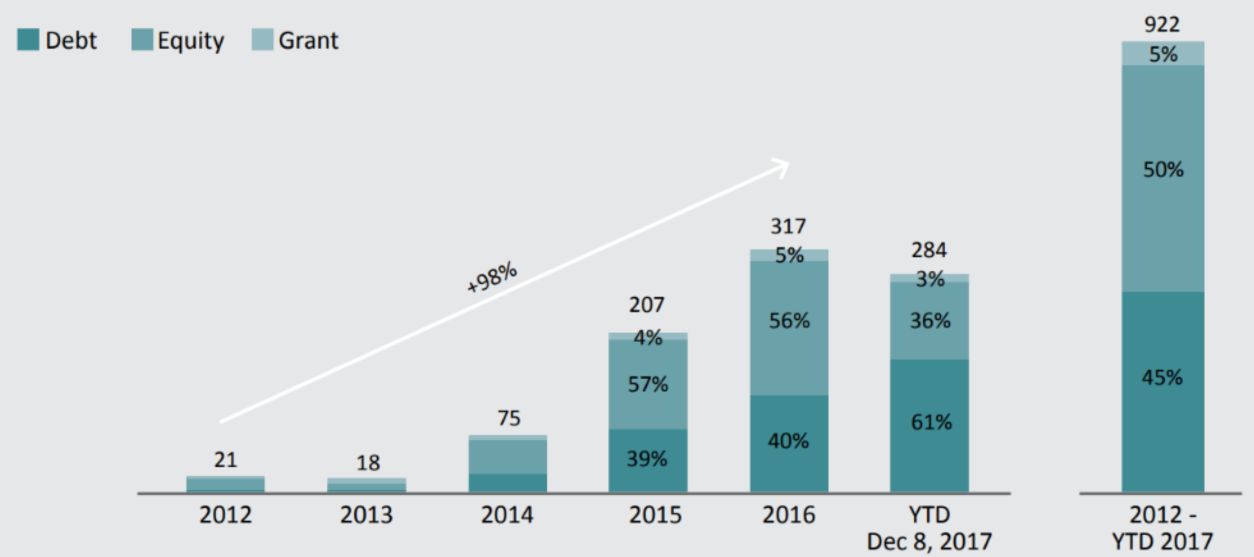
Solar Home System Kit
Quality Assurance Protocols

Version 2

December 2016

- SHS products must be:
  - tested to the latest edition of the Lighting Global Solar Home System Test Methods
  - by a test lab that is approved by Lighting Global to conduct the SHS tests
- SHS-QTM test results are required for Lighting Global's assessment to meet the SHS Quality Standards
- The Lighting Global SHS test methods can be obtained from the Lighting Global QA team upon request or from: https://www.lightingglobal.org/quality-assurance-program/testing-process/
- For more information please see https://www.lightingglobal.org/resource/benefits-of-harmonizing-test-methods-and-quality-standards/

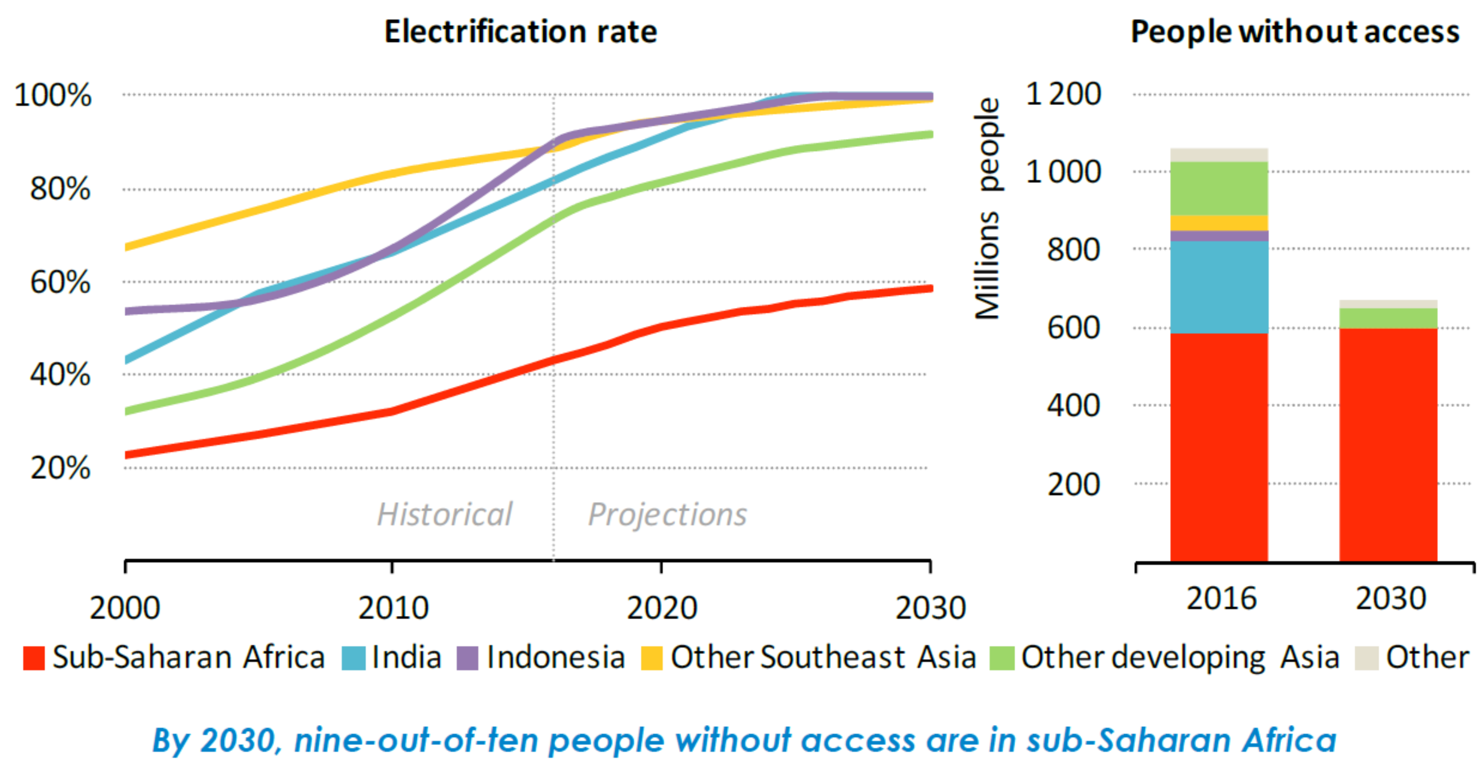
The PAYG SHS sector has been very successful in the last 5 years at raising money to grow this market…



	2012	2013	2014	2015	2016	YTD Dec 8, 2017
Avg. size of top 5 transactions	2.8	2.4	9.8	21.3	31.7	25.4
Avg. size of overall transactions	1.4	1.0	3.1	5.6	4.0	5.0
Number of transactions	15	18	24	37	79	57

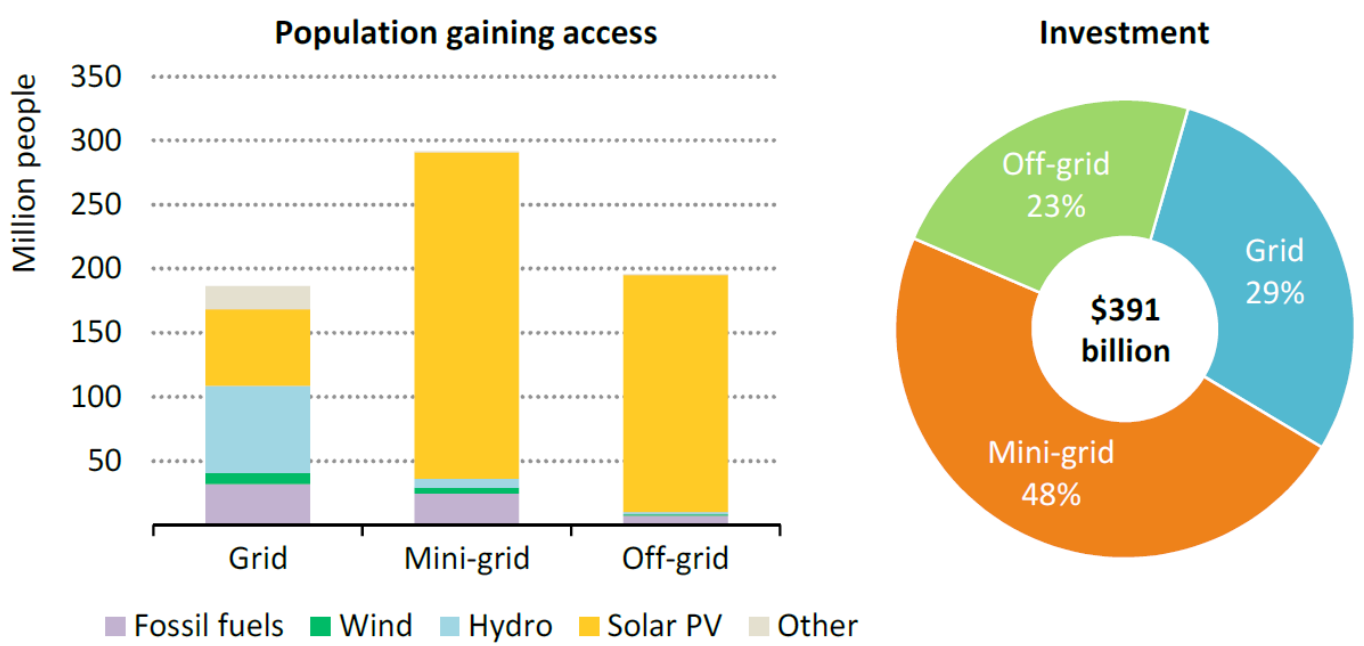
Source: GOGLA 2018 Market Report

…however with the IEA predictions for <60% of SSA (632m people) to be unelectrified by 2030 (based on current policy trends)…



Source: IEA Energy Access Outlook

…an additional $391bn is required to electrify everyone, with most investment coming through decentralised sources



Decentralised systems make up nearly three-quarters of the additional connections to meet universal electricity access by 2030

Source: IEA Energy Access Outlook

Summary: Closer alignment of decentralised and traditional electricity distribution methods needed over the next decade

- “Next Generation” Utility companies in the developing world will need to **work with a range of grid, mini-grid and off-grid solutions** to provide the most suitable electrification solution in a given area.
- The most appropriate solution will be selected for an area **based on a range of data sets** including usage profiles, geography and customer income levels.
- Ensuring that systems do not become stranded by allowing **interconnections to happen between SHS and microgrids** should be actively investigated.
- Financial support to the sector should become **more consistent and cover a wide range of solutions** to ensure IEA universal electrifications targets are met by 2030.
- Quality standards need to be **harmonised with international organisations** to ensure adoption by national governments.

Standardizing DC Microgrids for Rural Electrification

Considerations and Stakeholder Participation

Sarah Majok
Sarah Aggrey Consulting Engineers

SESDC Panel
August 8, 2018

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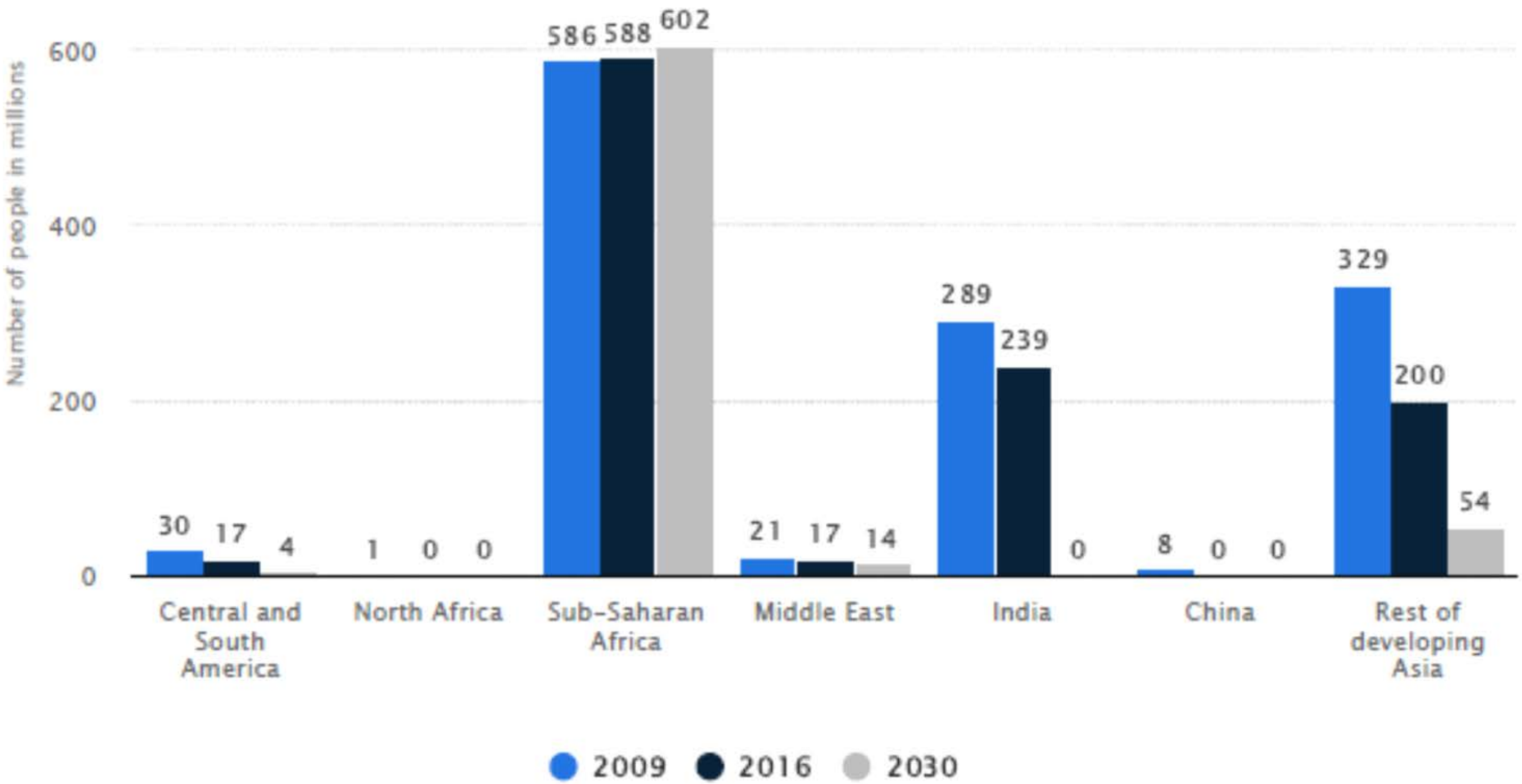
Overview

- Progress towards increasing electricity access
- Description of IEEE P2030.10 Standard
- Standards produce practical benefits
- Stakeholders role in developing standards
- Lessons learned thus far
- Additional considerations
- How you can join

Projected Population Without Electricity Access (Millions)



"Forecast of global populations lacking electricity access in 2009/2016/2030." Statista, https://www.statista.com/statistics/561428/forecast-of-population-without-access-to-electricity-globally-by-region/

IEEE P2030.10 Standard

- P2030.10 Working Group is developing a standard for DC microgrids for rural and remote electricity access applications.
- Scope includes design, operations, and maintenance
- Purpose is to provide safe and economic access to electricity and to facilitate clean renewable energy

Practical Benefits of Standardization

- Ensure safety.
- Streamline the architecture; reduce engineering cost.
- Facilitate reliability, quality, compatibility and interoperability.
- Simplify product development resulting in lower prices; promote economies of scale.
- Create trust.

Critical to P2030.10 Success

- Use cases
- Stakeholder participation
- Global adoption

Stakeholder Task Group

- The objective of this task group is to enable meaningful involvement by identified stakeholders and other interested parties.
- Stakeholders include governments, manufacturers, investors, banks, NGOs and any interested party.

Benefits of Stakeholder Participation

- For manufacturers or project developers, it gives them an opportunity to provide comments and feedback regarding practical applications.
- For financiers, it provides information which enables them to feel comfortable with the bankability, reliability or quality of an asset.
- For governments, it provides information which can potentially inform policies and regulations.

Stakeholder Anecdotes

- The best planning in the world doesn't anticipate how the customer will actually use the system. Engage the community.
- Customers are aspirational and will exceed the capacity of their system eventually.
- When systems malfunction and repairs are slow, public perception could turn.
- Power theft and tampering with systems is an ongoing issue.

Lessons Learned Thus Far…

- Standard development is challenging
- Many considerations need to be weighed carefully
- Focusing on the customer helps to clarify some of the considerations
- Use an approach that is grounded in real life experience
- Test the standard to ensure it meets objectives
- Involve and engage stakeholders early and often

Considerations

– No cohesive set of standards exists for low voltage off-grid DC microgrids.
– Develop something specifically for the developing world, not a stripped down version of an existing product in the developed world.
– Anticipate change such as load growth or future innovation and try to address it.

Additional Considerations

- Will standard result in a layer of regulation that increases the cost of systems?
- Enable the work being done to:
  - increase access by developing a market for reliable quality products
  - make systems affordable for remote communities
  - increase awareness and adoption amongst installers, manufacturers, governments, financial institutions

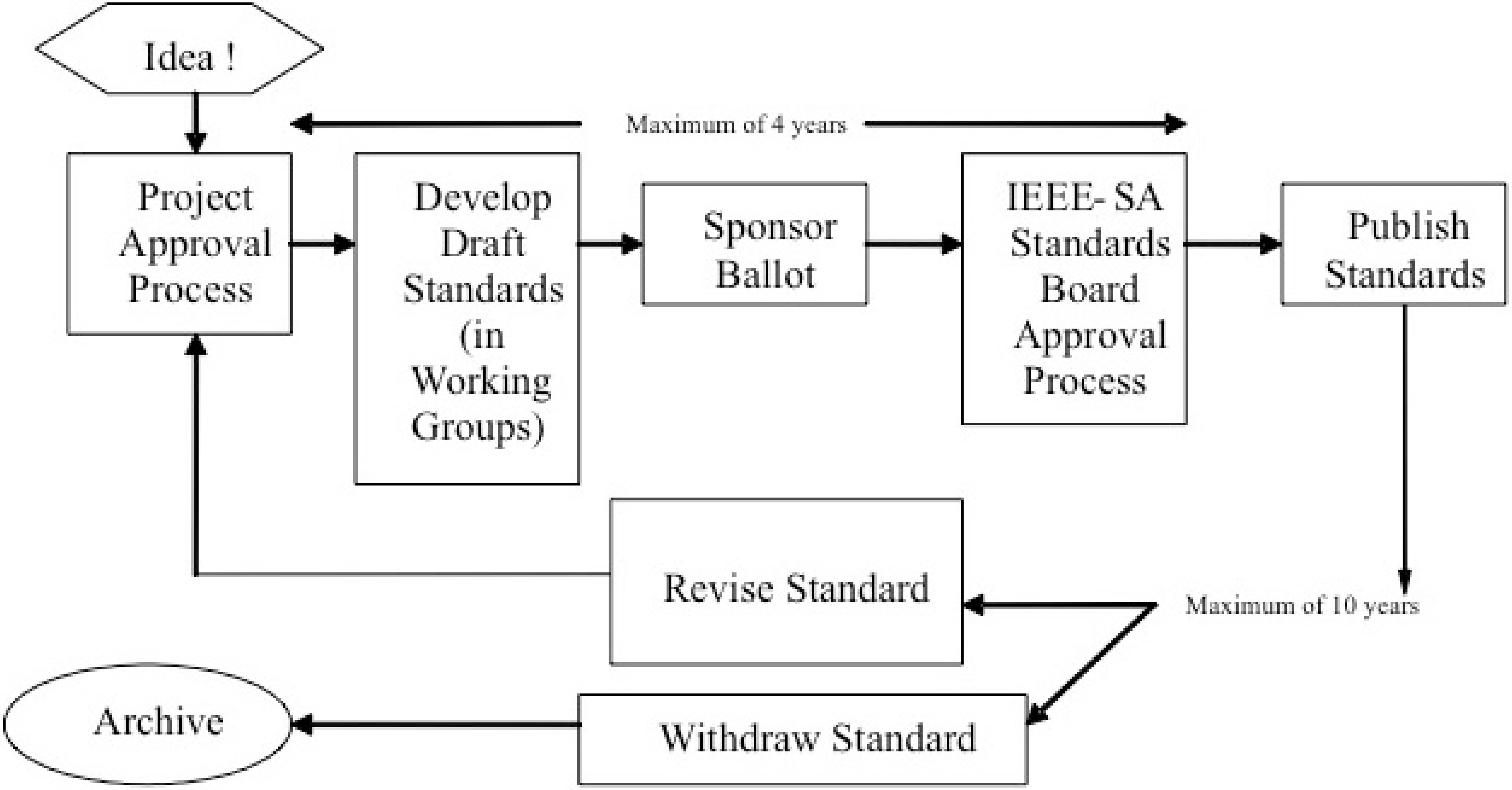
Additional Questions to Consider

- Does standardization stifle innovation?
- What is the right balance of cost and complexity?
- Who will engineer?
- How can power theft be addressed?
- How can loads be manage and prioritized?
- O&M: Who will maintain and repair the system?

How you can participate

- Join the P2030.10 working group
  - Meeting is 3rd Thursday of month at 8 AM PT
- Share your experience with off-grid systems
- Contribute to the draft standard
- Review the draft standard

Standards Development Overview



"How are standards made." IEEE Standards Association, http://standards.ieee.org/develop/process.html

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Contact

- Sarah Majok: smajok@sarahaggrey.com
- P2030.10- Distribution Resources Integration Working Group/Remote DC Microgrid website: http://sites.ieee.org/sagroups-2030-10/

Quality Assurance Framework for Mini-grids

Ian Baring-Gould
Technology Deployment Manager for Wind & Water
National Renewable Energy Laboratory
Golden, Colorado, USA

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A Quality Assurance Framework for Mini-Grids

To address the root challenges of providing quality power to remote consumers through financially viable mini-grids, the Global Lighting and Energy Access Partnership (Global LEAP) initiative of the Clean Energy Ministerial and the U.S. Department of Energy teamed with the National Renewable Energy Laboratory (NREL) and Power Africa to develop a Quality Assurance Framework (QAF) for isolated mini-grids. The framework addresses both alternating current (AC) and direct current (DC) mini-grids, and is applicable to renewable, fossil-fuel, and hybrid systems.

Mini-grids Quality Assurance Framework

- **Purpose:** Provide structure and transparency for mini-grids sector, based on successful utility models, while reflecting the broad range of service levels required to meet the needs of various segments of the off-grid consumer base
- **Importance:** Lay the foundation for successful business models in the mini-grids space

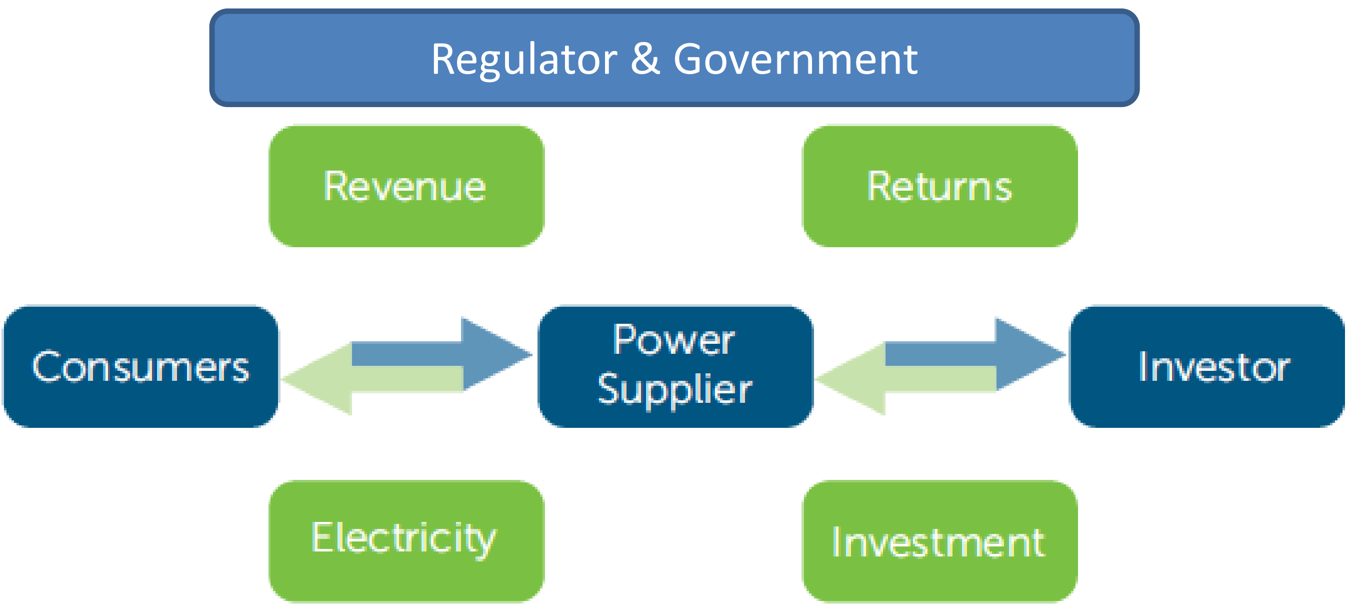
Source: Kari Burman, August 2007

A mini-grid is an aggregation of loads and one or more energy sources operating as a single system providing electric power, and possibly heat, isolated from a main power grid. A modern mini-grid may include renewable and fossil fuel-based generation, energy storage, and load control. Mini-grids are scalable so that additional generation capacity may be added to meet growing loads without compromising the stable operation of the existing mini-grid system.

The Mini-grid Utility Model

Business models for commercially viable mini-grids must address the needs of the four key stakeholder groups:

- **Customer:** Need a guarantee of service that they can afford and are willing to pay for
- **Power Suppliers:** Need to be able to guarantee a rate of return to their investors
- **Investors:** Need to be confident of the risks they are taking
- **Regulators & Government:** Sets the rules, keeps the peace and may contributed funds



Mini-Grids Quality Assurance: Unlocking Investment & Scale-up

- **Provide common technical standard for classifying service from mini-grids** based on well-defined system specifications for different levels of service
- **Strengthen revenue flows by optimizing system design** through more consistent system specifications that are better tailored to different tiers of consumer need and ability to pay
- **Facilitate aggregation, unlocking private investment** through adoption of uniform classification system coupled with accountability framework:
  - Bundle projects with similar attributes
  - Generate robust market information
- **Flexible and adaptable framework:** Which includes AC & DC mini-grids; applicable to renewable, fossil-fuel, and hybrid systems; capture basic to "grid-parity" service

Elements of the Quality Assurance Framework

1. **Define levels of service** tailored to different tiers of consumers, including appropriate thresholds for:
   - Power quality
   - Power availability
   - Power reliability
2. **Define accountability framework**
   - Clear process for verification of power delivery through trusted information to consumers, funders, and/or regulators
   - Provides defined assessment and reporting protocol for operators

The Quality Assurance Framework DOES NOT mandate a standard level of service but provides a more detailed, common way to reference levels of service.

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Peak Available Power (Watts)	None	>1 W	>20 W	>200 W	>2,000 W	>2,000 W
Consumption (kWh/year)	< 3	3 - 66	67 - 321	322 - 1,319	1,319 - 2,121	> 2,123
Duration of Supply (hours per day)	None	> 4 hrs	> 4 hrs	> 8 hrs	> 16 hrs	> 22 hrs
Evening Supply	n/a	> 2 hrs	> 2 hrs	> 2 hrs	4 hrs	4 hrs
Quality	n/a	low	low	Adequate	Adequate	Adequate
Typical Applications (Cumulative)	None	Radio, Task lighting	General Lighting, fans, TV, light office needs	Air cooling, food processing, and task oriented food preparation	Refrigeration, water heating, pumps, expanded food preparation	Air conditioning, space heating and full food preparation

Levels of Service for Isolated Mini-grids

1. **Power Quality** – Is the power provided of a reasonable or defined quality to safely provide the energy needs of the consumers?
   - Voltage and frequency variations, distortion etc.
2. **Power Availability** – Is the power provided in the amount that meets expectations and available with the duration that has been specified?
   - Hours of service, power and energy levels, etc.
3. **Power Reliability** – Is the power provided with enough reliability to meet consumer needs?

Source: Kari Burman, November 2016

Source: Solar Nigeria, 2014

Mental Model – Rural Energy Needs

- A heavy duty pick-up truck is a good mental model of “grid parity” power. It’s great to have but expensive to own and operate.
- Most people in rural communities don’t have the need for grid parity power supply, a moped is more appropriate and much lower cost.

Power Quality Issues

- Voltage Unbalance (AC)
- Transients (AC & DC)
- Short Duration Variations (AC & DC)
- Long Duration Variations (AC & DC)
- Waveform Distortion (AC & DC)
- Voltage Fluctuations/Flicker (AC & DC)
- Frequency Variations (AC)

AC Power Quality Issues

Issue	Base Level of Service	Standard Level of Service	High Level of Service
AC Power Quality Phenomena			
Voltage imbalance	<10%	<5%	<2%
Transients	No protection	Surge protection	Surge protection
Short voltage duration variations	<5/day	<1/day	<1/week
Long voltage duration variations	<10/day	<5/day	<1/day
Frequency variations	48 Hz < f <52 Hz	49 Hz < f <51 Hz	49.5 Hz < f <50.5 Hz

- Voltage phase unbalance
- Transients outside of system insulation design
- Short duration voltage variations due to faults lasting <1min
- Long duration voltage variations due to faults lasting >1min
- Voltage waveform Distortion- Fluctuations/Flicker
- Frequency Variation

What is Power Availability?

- The amount of energy services being provided to specific customers based on need and other factors. Three main criteria :
  1. **Power:** Maximum draw in Amps or Watts
  2. **Energy:** Total energy available (kWh) over a defined time period (month, year)
  3. **Time of day service:** For what hours of the day is power available (hours per day)
- Availability ties together the parameters that define how much energy service is to be provided to a specific customer based on their ability and willingness to pay for that service. Expected to change over the life of the utility/customer relationship
- Consistent with the World Bank Multi-Tier Framework but expands on the details taking a more power system focused approach

Energy Available Per Time Period

- Would typically be tabulated over a period of time (month or year) even if pre-pay meters focused on energy were used
- Minimum and maximum levels of service for different customers could be specified
- Different rates could be applied to different levels of service

Energy Level	Peak Level (kWh/year)
Level 1	>4.38
Level 2	>73
Level 3	>365
Level 4	>1,250
Level 5	>3,000
Level 6	>73000

Power Reliability

Represents how well the power system provides power during times when power should be provided.

- **Unplanned power outages**
  - o System Average Interruption Frequency Index (SAIFI)
  - o System Average Interruption Duration Index (SAIDI)

Source: Canadian Pacific, flickr 2013

- **Planned power outages**
  - o Planned System Average Interruption Frequency Index (P-SAIFI)
  - o Planned System Average Interruption Duration Index (P-SAIDI)

Power Reliability - Unplanned Outages

Unplanned Outages:

Level of Service	SAIFI Interruption$_{24}$ Frequency*	SAIDI$_{24}$ Interruption Duration*
Base	<52 per year	<52,560 minutes (876 hours) 90% reliability
Standard	<12 per year	<26,280 minutes (438 hours) 95% reliability
High	<2 per year	<90 minutes (1.5 hours) 99.99% reliability

*SAIDI and SAIFI values provided assume 24 hours per day of expected service. If fewer than 24 hours per day are to be provided, an adjustment of the specific threshold values for SAIFI and SAIDI should be made and a subscript added to reflect the expected hours of service per day.

Planned Outages:

Level of Service	P-SAIFI$_{24}$ Interruption Frequency*	P-SAIDI$_{24}$ Interruption Duration*
Base	No requirement but should be defined	No requirement but should be defined
Standard	No requirement but should be defined	No requirement but should be defined
High	<2 per year	<30 minutes - 100% reliability

*P-SAIDI and P-SAIFI values provided assume 24 hours per day of expected service. If fewer than 24 hours per day are to be provided, an adjustment of the specific threshold values for P-SAIDI and P-SAIFI should be made and a subscript added to reflect the expected hours of service per day.

Accountability Framework

1. **Consumer Accountability** defines, demonstrates, and validates that a specific level of service is being provided to a customer
   - Level of Service verification
   - Service Agreement

Source: NREL PIX #07805

2. **Utility Accountability** allows funding or regulatory organizations to understand if the system is safe and providing contracted service
   - Technical reporting
   - Business reporting
   - Reporting template

Source: Jake Lyell for the Millennium Challenge Corporation

Consumer Accountability Framework

Level of Service Verification

- Ability to record energy consumption
- Ability to record hours of service at service drops
- Ability to check voltage levels at service drops
- Implementation of periodic, random, and documented voltage surveys to ensure proper quality of service

Service Agreement

- Defines applicable power quality standards in place
- Identifies what type of investigation is warranted based on complaints
- Describes how to address power quality impacts caused by the customer vs. those caused by the power system (utility)

Utility Accountability Framework

Provides a defined and secure methodology for utilities to provide relevant information to regulators and project financiers, essentially the information that will allow a good understanding of the utility business

Information about the performance of the utility

- Technical Reporting: Measurements addressing system performance, energy usage, operational issues
- Business Reporting: Payment collection rates, electrification rates, customer characteristics, service calls and safety concerns, etc.

Reporting Template

- Standard document or procedure that provides performance information to the funder/regulator, providing consistency across energy platforms and projects.

Mini-Grid Implementation – Stakeholder Mapping

Program Development Step	Regulator	Ministry	Developers	Mini-utility	Investors	Customers
1. Specify project goals	●	●			●	
2. Develop policy and ownership frameworks	●	●				
3. Develop reporting and measurement requirements	●	●	●	●	●	
4. Develop performance, monitoring, and reporting plans/procedures	●	●		●	●	
5. Develop a project or program quality assurance verification process	●	●		●	●	
6. Develop program and project documentation	●	●			●	
7. Implement quality assurance verification process	●	●			●	
8. Implement the electrification/mini-grid deployment project	●	●	●	●	●	●
9. Collect and analyze long-term system operational data	●			●	●	●

The QAF is designed to help governments understand each of these steps in the development of minigrid power systems in a uniform, industry consistent way

A Quality Assurance Framework for Mini-Grids

All documents available at:
https://cleanenergysolutions.org/qaf

- Technical Report
- Implementation Guide
- Fact sheet and presentation

Technical documents being added: Commissioning guide, load forecasting tools, community surveys etc..

Supported by:

- Global Lighting and Energy Access Partnership (Global LEAP) initiative of the Clean Energy Ministerial and the
- U.S. Department of Energy teamed with the
- National Renewable Energy Laboratory
- Power Africa

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Questions and Contact Information

Ian Baring-Gould

303-384-7021

Ian.baring-gould@nrel.gov

https://cleanenergysolutions.org/qaf

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U.S. DEPARTMENT OF ENERGY

CLEAN ENERGY MINISTERIAL Accelerating the Global Clean Energy Transition

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University of Strathclyde Glasgow

Overview of IEC standards activities on LVDC for electricity access

Dr Abdullah Emhemed & Professor Graeme Burt
Institute for Energy and Environment
University of Strathclyde
abdullah.emhemed@strath.ac.uk graeme.burt@strath.ac.uk
Glasgow-United Kingdom

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Overview

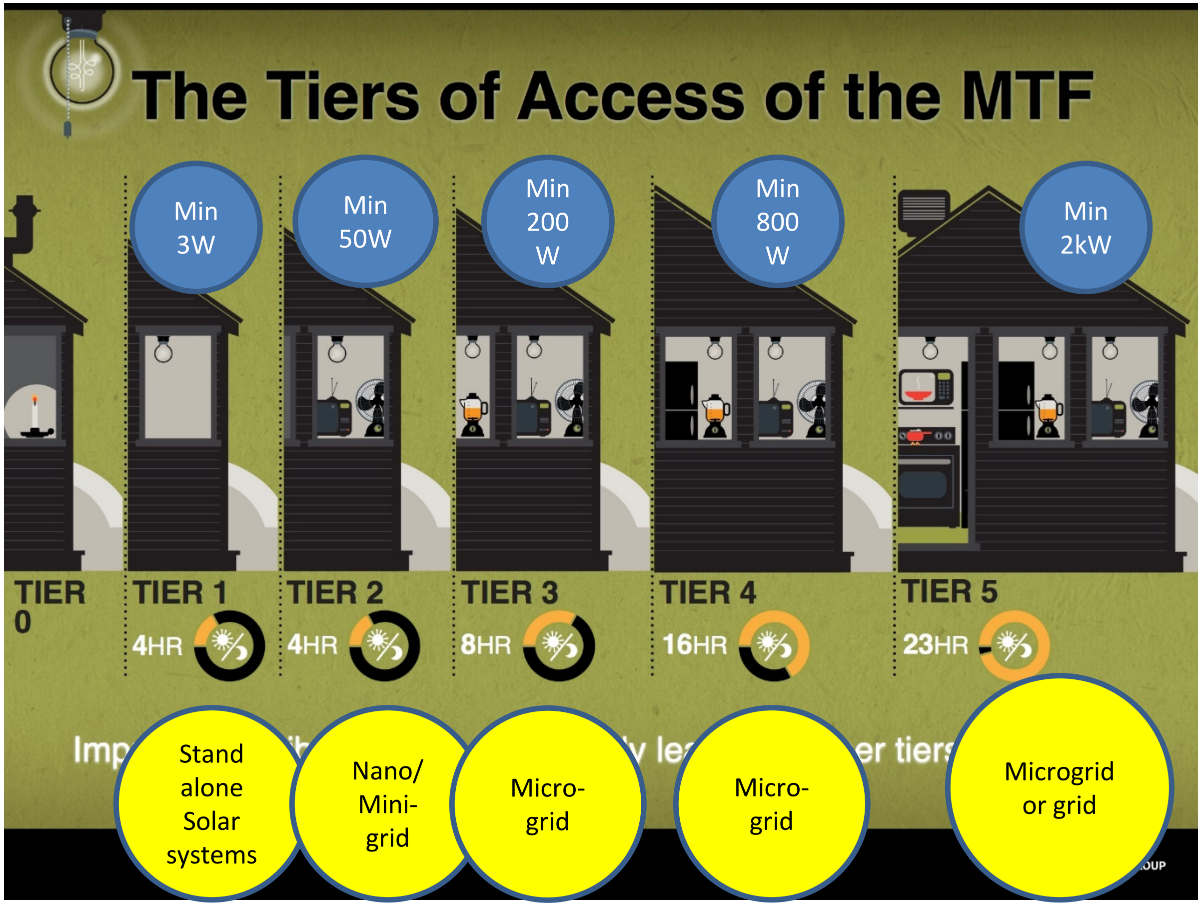
- Introduction to electricity access
- How can DC infrastructure help?
- Challenges with LVDC for electricity access
- Standards for LVDC
- Overview of IEC work relevant to LVDC

What is electricity access?

- Electricity is a key driver for better economy, improved education and healthcare, and reduced poverty
- But... over 1.2. billion people are without access to electricity

https://iecetech.org/issue/2016-08/Standardization-can-help-millions-access-electricity

What is electricity access?



World Bank five classes multi-tiers electricity access definition

http://www.worldbank.org/en/topic/energy/publication/energy-access-redefined

How can DC infrastructure help?

- Small scale off-grid installation is more feasible than grid extension for electricity access based on local resources
- PVs cost is declining and making significant changes in electricity access
- PVs generate DC and loads such as LED lighting requires DC supply
- “LVDC bridges the gaps between the solar photovoltaic (PV) generation and the consumption devices in the home”
- No synchronisation issue and easier to control
- Reduced conversion stages between sources and loads
- More connection with LVDC, higher tiers of energy access can be achieved

> 3.9 million solar home systems have been installed in Bangladesh

41million household in India to be electrified to meet 2019 universal electrification target

40GW solar power generation by 2022

LVDC for electricity access: opportunity and standards, LVDC International Conf. May 2018, Hangzhuo, China

Challenges with LVDC

- LVDC is still considered as a highly disruptive technology
- LVDC needs to be safe and reliable, at least to the same extent as AC systems
- There is still a lack of standards, with no consensus on DC voltages, earthing for islanded microgrid arrangements, protection solutions, plugs, sockets, etc.

Standards for LVDC

- The standards will help to make LVDC technology safe for different applications
  - Inc. rural electrification, data centres, offices, last mile, etc.
- IEC has almost 30 TCs which may need to be modified to include DC
  - Allows the use of existing AC standards and knowledge relevant to DC
  - Requires systems level standards to cover all aspects relevant to DC products and systems

Standards for LVDC

- Nov'14
  - IEC Systems Evaluation Group (SEG4) established to evaluate LVDC applications, distribution & safety for developed and developing economies
- 2016
  - SEG4 concludes: "a very large number of publications, issued by over 30 IEC TCs, are concerned and will need updating" to include requirements for DC
- Feb'17
  - IEC Standardisation Management Board (SMB) established a new Systems Committee on LVDC & LVDC for Electricity Access.

Standards for LVDC

IEC LVDC Systems Committee

To provide technical foundation and guidance of LVDC systems in developed and developing countries

http://www.iec.ch/lvdc/

Coordination Advisory Group (CAG1)

- LVDC markets and use cases review for Standards
- Recommendations on industry needs for standardization
- Highlight areas for future cooperation with external stakeholders
- Promoting IEC LVDC work and Standards.

Coordination Advisory Group (CAG2)

- Responsible for internal coordination and implementation of the work carried out by different TCs and subcommittees.

Working Group1

- LVDC publications for electricity access

https://iecetech.org/issue/2016-08/Standardization-can-help-millions-access-electricity

https://www.esi-africa.com/electricity-access/

Overview of IEC work relevant to LVDC

Existing IEC TCs effort relevant to DC

- IEC TC 82: Solar PV energy systems (develop standards and publications for PV systems including power converters and inverters & and recommendations for solar PV in rural decentralised electrification (IEC 62257 series))
- IEC TC 20: Electric cables, prepare standards for the design, testing for power cables and their accessories
- IEC TC 22: Power electronic systems and equipment, including DC converters
- IEC TC 8: Systems aspects for electrical energy supply
- IEC TC 64: Protection against electric shocks
- IEC TC 23: Electrical accessories: AC&DC operation
- IEC TC 32: Fuses

Overview of IEC work relevant to LVDC

Work in progress

- IEC TC 64:
  - PT 101, Application Guide: Residential electrical installation in direct current not intended to be connected to Public Distribution Network
  - IEC 60364-41 to introduce DC RCD
  - IEC 60364-42 to improve requirements for preventing the risk of fire
  - IEC 60364-43 to improve short circuit calculations
  - IEC 60364-5-54 on requirements to prevent corrosions
- IEC/TS63053 RCD for DC application
- IEC 60898-3 Circuit Breakers for DC application

Summary

- LVDC has the potential to accelerate electricity access by **providing a modular infrastructure** to scalably connect PV, storage, and loads
- There are many devices that work with DC**, but standards on interfacing DC supplies are missing**
- No standards are available for LVDC for electricity access yet.

But

- A number of IEC TCs deal with areas relevant to LVDC in their current scope, **and greater effort from different stakeholders is now required** to promote relevant solutions