Rural electrification for universal electricity access

Access to electricity

An estimated 1,2 billion people have no electricity connection. Another estimated 2,7 billion people have only very limited access to electricity. In total they represent 53% of the world's population.

photo credit: energyrenaissance.com.au

But energy access is not an on-off paradigm. In the past energy access was considered synonymous with grid connection. It was defined as an "electric pole in the village" and an "electric light bulb" in the house. Of course, this doesn't take into account the quantity or quality of electricity and if and when it is provided. Unreliable and intermittent electricity access defies the purpose it strives for. It doesn't enable economic growth, because one can't count on it.

There are many basic and affordable technical solutions that can bring electricity to populations that will otherwise have to wait possibly many more years for a grid connection.

The IEC provides the technical foundation that facilitates the building of safe and affordable off-grid infrastructure that can later on be connected and expanded. IEC International Standards also guide their design and installation and with it the bench-marking and comparison of such infrastructure investment.

This brochure provides an overview of different technologies and relevant IEC International Standards that facilitate off-grid electricity access.

The IEC is a partner of IRENA, UN SE4ALL, ARE, AFSEC, and many other organizations.

IRENA
International Renewable Energy Agency

SUSTAINABLE
ENERGY FOR ALL

Alliance for
Rural
Electrification
Shining a Light for Progress

AFSEC

Electrification of remote areas

Electric power is the corner stone for economic development, better healthcare, increased safety, education as well as efficiency gains in agriculture and manufacturing.

In an ideal world, everybody would be connected to efficient power grids that deliver electricity 24/7. Unfortunately, when the grid is too far away or clusters of users are too small to make grid access economic, grid connection can be too complex or expensive to put in place or could take years until completion. In such cases, both in developed and developing countries, autonomous power systems can bridge the gap.

Decentralized rural electrification systems (DRES) are designed to supply electric power for sites which are not connected to an electricity network. They provide basic electricity access for household, community services (public lighting, pumping, health centres, administrative buildings, places of worship, cultural activities) and for economic activities in the form of micro-industry, workshops or agriculture.

IEC work for DRES provides the technical specifications that allow project developers, implementers and installers to select the right system for the right place. They support system design, operation and maintenance.

photo credit: Kuni Takahashi NY Times

DRES fall into three basic categories:

- → Process electrification systems, for example for irrigation and the pumping of ground water
- → Individual electrification systems (IES) for sparsely populated regions or isolated individual households
- → Collective electrification systems (CES) for more densely populated areas, for example a large village

Process and individual electrification systems comprise a relatively simple electricity generation system combined with a single electrical installation.

Collective electrification systems also include a distribution system (microgrid) and interface equipment that links the individual electrical installation of each user to the microgrid.

Ensuring short-term success and long-term viability

When developing a policy of electrification, it is necessary to consider the medium (10 years) as well as the long term (20 to 30 years) outcomes. Such a plan needs to include both the extension of existing electricity grids, as well as individual or collective autonomous electrification systems.

Optimal results depend on the ability to interconnect decentralized electricity systems at a later time. This requires that the same technical rules are applied for all projects that later need to be interconnected.

Decentralized electrification generally requires a range of systems. For example, the use of hybrid micropower plants that combine Renewable Energy generation with battery storage can allow for a better reliability of the power supply. Electricity can be made available to the microgrid during a greater part of the day or even all day. In some cases generators may be needed to complement renewable power supply.

photo credit: durgasolar.org

Electricity access: a planned approach

The IEC provides a planned and tested approach to building rural electrification projects. We propose a method developed in a public/private partnership that included organizations such as the World Bank Group, the United Nations Foundation, the US Department of Energy, research laboratories, universities and private industry.

This method outlines international best practices in support of energy access across a range of technologies.

The IEC 62257 series of Technical Specifications includes a methodology that allows for the selection of the most cost-effective DRES and provides guidelines for an electrification master plan. It includes charts that outline advantages and disadvantages of single and multiple user systems.

The different parts of the series are structured in a way that follows the phasing of a typical DRES project:

Opportunity study

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This part covers all the different options and introduces advantages or disadvantages of collective or individual solutions. It includes guidance on how to develop an electrification master plan (where to develop the national grid and where to develop off-grid electrification) as well as a time table of electrification and indications regarding necessary investment.

Specification

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This part presents a range of systems and provides assistance in selecting the right system according to the quantity of power needed or service quality required. It also includes standardized systems architectures, location analysis, how to evaluate project size, electrification mapping, etc.

Feasibility

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This step is essential to choosing the right technical solutions and writing the general specification. It comprises considerations that cover technical and economic aspects; assessment of available Renewable Energy resources; socio economical studies; business plan and other guidance.

Detailed technical study

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This part covers the writing of a general specification, including for example maximum available power needed, average daily or weekly hours of energy provided, power quality criteria. It also contains details on the level of safety future electrical installations shall offer, including for example the safety of persons, risks of fire, over-voltages, lightning protection, and so forth.

Implementation

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During this phase the electrical installations are built in the field and commissioned. IEC work provides guidance for the erection and commissioning of an array of different electrical devices and equipment, for example for:

→ Photovoltaic arrays and PV electrification systems
→ Generators
→ Batteries
→ Micropower systems including renewable and hybrid elements
→ Microgrids
→ Indoor installations
→ PV portable lanterns or compact fluorescent lamps
→ Off-grid household appliances (currently in development)

It also provides simple tests to ensure the quality and safety of installations. These tests are designed in a way so that they can be performed by local organizations with very simple equipment.

Validation

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This step helps to verify how the delivered service compares to the service level defined in the contract; if the power quality and quantity are according to specifications.

In field operation

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This phase is of utmost importance to ensure the permanence of the installation and service provided to the customer. It comprises operation, maintenance, replacement, management, recycling, quality of service, quality of management, customer relationship.

photo credit: berg.berkeley.edu

Hereafter a detailed list of each part of the IEC 62257 series:

Introduction to IEC 62257 series and decentralized rural electrification

IEC TS 62257-1	Recommendations for renewable energy and hybrid systems for rural electrification – Part 1: General introduction to IEC 62257 series and rural electrification

Management of project – Rules for designing, managing and operating rural electrification systems

IEC TS 62257-2	Recommendations for renewable energy and hybrid systems for rural electrification – Part 2: From requirements to a range of electrification systems
IEC TS 62257-3	Recommendations for renewable energy and hybrid systems for rural electrification – Part 3: Project development and management
IEC TS 62257-4	Recommendations for renewable energy and hybrid systems for rural electrification – Part 4: System selection and design
IEC TS 62257-5	Recommendations for renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards
IEC TS 62257-6	Recommendations for renewable energy and hybrid systems for rural electrification – Part 6: Acceptance, operation, maintenance and replacement

Technical specifications

IEC TS 62257-7	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7: Generators
IEC TS 62257-7-1	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic arrays
IEC TS 62257-7-3	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-3: Generator set – Selection of generator sets for rural electrification systems
IEC TS 62257-8-1	Recommendations for small 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 62257-9-1	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-1: Integrated systems – Micropower systems
IEC TS 62257-9-2	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-2: Integrated systems – Microgrids
IEC TS 62257-9-3	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-3: Integrated systems – User interface
IEC TS 62257-9-4	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-4: Integrated systems – User installation
IEC TS 62257-9-5	Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-5: Integrated systems – Selection of stand-alone lighting kits for rural electrification
IEC TS 62257-9-6	Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9-6: Integrated system – Selection of Photovoltaic Individual Electrification Systems (PV-IES)
IEC TS 62257-12-1	Recommendations for renewable energy and hybrid systems for rural electrification – Part 12-1: Selection of lamps and lighting appliances for off-grid electricity systems

The IEC, World Bank Group and United Nations Foundation provide developing countries with access to the IEC 62257 series at a specially discounted price. For more information visit: go.iec.ch/ruralfaq

Solar power

In many developing countries, solar energy is abundant and can fruitfully be harnessed. With decreasing photovoltaic (PV) prices and increasing PV energy output, power from the sun is an important component of DRES projects. PV modules are often combined with battery energy storage or sometimes diesel generators to maximize energy delivery after dark.

The use of IEC International Standards together with testing and certification services provided by the IEC Conformity Assessment Systems helps ensure and verify the safety, long-term performance, energy yield and resistance to environmental conditions of solar power generation modules.

photo credit: eai.in

Hereafter a list of IEC International Standards for energy access through solar PV:

IEC 60891	Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics
IEC 60904-10	Photovoltaic devices – Part 10: Methods of linearity measurement
IEC 61215 series	Terrestrial photovoltaic (PV) modules
IEC 61345	UV test for photovoltaic (PV) modules
IEC 61646	Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC 61683	Photovoltaic systems – Power conditioners – Procedure for measuring efficiency

IEC 61701	Salt mist corrosion testing of photovoltaic (PV) modules
IEC 61724	Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis
IEC 61725	Analytical expression for daily solar profiles
IEC 61730 series	Photovoltaic (PV) module safety qualification
IEC 61829	Photovoltaic (PV) array – On-site measurement of current-voltage characteristics
IEC TS 61836	Solar photovoltaic energy systems – Terms, definitions and symbols
IEC 61853 series	Photovoltaic (PV) module performance testing and energy rating
IEC 62093	Balance-of-system components for photovoltaic systems – Design qualification natural environments
IEC 62108	Concentrator photovoltaic (CPV) modules and assemblies – Design qualification and type approval
IEC 62109 series	Safety of power converters for use in photovoltaic power systems
IEC PAS 62111	Specifications for the use of renewable energies in rural decentralised electrification
IEC 62124	Photovoltaic (PV) stand alone systems – Design verification
IEC 62253	Photovoltaic pumping systems – Design qualification and performance measurements
IEC TS 62257 series	Recommendations for renewable energy and hybrid systems for rural electrification
IEC 62446-1	Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection
IEC 62509	Battery charge controllers for photovoltaic systems – Performance and functioning
IEC TS 62548	Photovoltaic (PV) arrays – Design requirements
IEC 62670 series	Photovoltaic concentrators (CPV) – Performance testing

IEC 62716	Photovoltaic (PV) modules – Ammonia corrosion testing
IEC TS 62727	Photovoltaic systems – Specification for solar trackers
IEC 62759-1	Photovoltaic (PV) modules – Transportation testing – Part 1: Transportation and shipping of module package units
IEC TS 62782	Photovoltaic (PV) modules – Cyclic (dynamic) mechanical load testing
IEC 62788-1 series	Measurement procedures for materials used in photovoltaic modules – Encapsulants
IEC TS 62789	Photovoltaic concentrator cell documentation
IEC 62790	Junction boxes for photovoltaic modules – Safety requirements and tests
IEC TS 62804-1	Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon
IEC 62817	Photovoltaic systems – Design qualification of solar trackers
IEC 62852	Connectors for DC-application in photovoltaic systems – Safety requirements and tests
IEC TS 62941	Terrestrial photovoltaic (PV) modules – Guideline for increased confidence in PV module design qualification and type approval

photo credit: efficiency4access.org

Micro and pico hydropower

photo credit: peilinggan.com

For most people the word hydropower evokes pictures of massive installations and large dams, yet the potential of small hydroelectric projects is huge and expanding.

Countries throughout the world, including China, India or Europe are investing in small hydro projects to bring power to rural communities, meet their overall energy requirements and reduce their dependence on imports of oil and gas.

Pico and micro hydro can help satisfy growing energy needs without having to build vast transmission infrastructure. Many of these hydro systems can be installed in days or weeks rather than years. Micro hydro schemes can be as large as 500 kW and are generally run-of-the-river developments for multiple users. Pico hydro systems have a capacity of 50 W to 5 kW and are generally appropriate for individual or small clusters of households.

One of the most important IEC International Standards for small hydroelectric installations is IEC 61116. It describes the installation and operating conditions of such power stations, equipment specifications as inspection, delivery, operation and maintenance. Another important Standard is IEC 62006 for hydraulic machines. It includes acceptance tests for small hydroelectric installations and especially those containing impulse or reaction turbines.

Hereafter a list of relevant IEC International Standards for energy access through hydropower:

IEC 60041	Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines
IEC 60308	Hydraulic turbines – Testing of control systems
IEC 60545	Guide for commissioning, operation and maintenance of hydraulic turbines
IEC 61116	Electromechanical equipment guide for small hydroelectric installations
IEC 61362	Guide to specification of hydraulic turbine governing systems
IEC 61366 series	Hydraulic turbines, storage pumps and pump-turbines
IEC 62006	Hydraulic machines – Acceptance tests of small hydroelectric installations

photo credit: peilinggan.com

Wind power

photo credit: energy4humandevelopment.com

Wind energy has been used for centuries for pumping water or milling grains. Today it is seen as offering the greatest potential for growth in the renewable energies' domain. Converting wind energy into electricity is clean, renewable and sustainable. Small wind turbines are able to generate between 1 kW and 100 kW of power for residential homes, farms, small businesses or schools.

Since wind doesn't always blow the fiercest when it is most needed, it is best combined with some form of energy storage, usually batteries. Wind is often also complemented with solar PV systems.

IEC 61400 is the most important series of Standards for wind turbines. It provides guidelines for safety including for small turbines, their design requirements, acoustic noise measurement techniques, power performance and robustness tests in line with wind strengths, abrasion rates and installation locations.

IEC 61400 series	Wind turbines

photo credit: thenational.ae

Energy storage

photo credit: energystoragealliance.com.au/

Generally electricity is consumed when it is produced. However, since both wind and solar are intermittent sources of energy, they are not always available when they are most needed. Storing energy for later use is an essential approach to achieve more sustainable energy generation. It helps optimize how and when power can be used.

The IEC has a special technical committee that focuses on electrical energy storage systems, as well as technical committees that prepare the International Standards that ensure the safety, power output and reliability of all types of batteries and fuel cells.

Hereafter a list of relevant IEC International Standards for energy storage:

IEC 62933 series	Electrical Energy Storage (EES) systems (*published soon*)
IEC 61056 series	General purpose lead-acid batteries (valve-regulated types)
IEC 61427 series	Secondary cells and batteries for photovoltaic energy systems – General requirements and methods of test
IEC 61951 series	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells
IEC 61959	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Mechanical tests for sealed portable secondary cells and batteries
IEC 61960	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications
IEC 62133	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications
IEC 62281	Safety of primary and secondary lithium cells and batteries during transport
IEC 62282 series	Fuel cell technologies
IEC 62485 series	Safety requirements for secondary batteries and battery installations
IEC 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for large format secondary lithium cells and batteries for use in industrial applications
IEC 62620	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for use in industrial applications

LVDC

photo credit: Adrian Pope, freepressjournal.in

Low voltage direct current (LVDC) will be one of the most useful technologies for rural electrification in the close future. It is a low cost, simple yet high-level technology that will make it easier to connect Renewable Energy especially in off-grid environments.

The LVDC movement is following the trend towards Renewable Energy generation. Solar PV generates direct current. And yet – even in rural settings – this energy is transformed into alternating current. This makes little sense and results in unnecessary efficiency losses. Today's world is already a direct current world: LED lamps, TV and multimedia devices, mobile phones, solar lights, PCs, all function perfectly well with direct current.

Many relevant Standards are already published or being upgraded to take into account the differing needs of direct current vs. alternating current. The IEC is globally leading the work that will ensure that LVDC is perfectly safe and relevant in almost all electrical applications, including in rural homes. LVDC standardization also represents a unique opportunity to develop a universal set of plugs and sockets.

If you are interested in learning more about LVDC: contact@iec.ch

Other IEC International Standards relevant for rural electrification

photo credit: Bruno Déméocq, Lighting Africa

Low-voltage electrical installations

IEC 60364 series	Low-voltage electrical installations
IEC 60375	Conventions concerning electric and magnetic circuits

Electric cables and installations

IEC 60227 series	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V
IEC 60287 series	Electric cables

IEC 60669-1	Switches for household and similar fixed-electrical installations – Part 1: General requirements
IEC 60947 series	Low-voltage switchgear and controlgear
IEC 61439 series	Low-voltage switchgear and controlgear assemblies

Lamps and lighting

IEC 60432 series	Incandescent lamps
IEC 60598 series	Luminaires
IEC 60969	Self-ballasted compact fluorescent lamps for general lighting services - Performance requirements
IEC 61347 series	Lamp controlgear
IEC 62031	LED modules for general lighting - Safety specifications
IEC 60038	IEC standard voltages

Safety and environment

(EMC, classification, fire hazard, circuit breakers, electric shock, insulation)

CISPR 22	Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement
IEC 60068 series	Environmental testing
IEC 60071 series	Insulation coordination
IEC 60269 series	Low-voltage fuses
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60664 series	Insulation coordination for equipment within low-voltage systems
IEC 60695-2-10	Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure
IEC 60695-2-12	Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability index (GWFI) test method for materials
IEC 60721 series	Classification of environmental conditions
IEC 61000 series	Electromagnetic compatibility (EMC)

IEC 61009 series	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)
IEC 61140	Protection against electric shock – Common aspects for installation and equipment
IEC 61180	High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment
IEC 61643 series	Low voltage surge protective devices
IEC 61858 series	Electrical insulation systems - Thermal evaluation of modifications to an established electrical insulation system (EIS)
IEC 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
IEC 62305 series	Protection against lightning

The IEC in brief

A global network of 170 countries

Global reach covering 99.1% of the world population and 99.2% of electricity generation

87 developing countries participate free of charge in the IEC Affiliate Country Programme

We make International Standards and run four Conformity Assessment Systems to verify that electronic and electrical products work safely and as they are intended to

IEC International Standards represent a global consensus of state-of-the art know-how and expertise

We are a global, non-governmental organization

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Key figures

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170
Members and Affiliates

213
Technical Committees

20 000
Experts from industry, test & research labs, government, academia and consumer groups

9 000
International Standards in catalogue

4
Global Conformity Assessment Systems

>1 million
Conformity Assessment Certificates issued

100+
Years of expertise

Global reach

Making electrotechnology work... for everyone

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The IEC provides much of the global technical framework for energy generation and for the billions of components, devices and systems that use electricity and contain electronics.

Part of our mission is to ensure and verify safety, efficiency and interoperability of off-grid and on-grid infrastructure and improve energy efficiency, the world's largest untapped energy source.

Broad concensus

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We have agreements with close to 200 organizations and provide a worldwide platform to around 20 000 global experts from both private and public sectors.

Partnerships

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We work closely with the International Organization for Standardization (ISO) and the International Telecommunication Union (ITU).

We have a strategic partnership with the World Trade Organization (WTO) to promote free and fair trade.

The IEC is a partner of the United Nations Sustainable Energy for All initiative (SE4ALL).

IEC and Sustainable Development Goals (SDGs)

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Access to energy can be viewed as the golden thread that supports the attainment of most of the 17 SDGs and their sustainability once met. IEC work fully corresponds with SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all.

photo credit: Greenpeace

Notes

Further information

Please visit the IEC website at www.iec.ch for further information. In the "About the IEC" section, you can contact your local IEC National Committee directly. Alternatively, please contact the IEC Central Office in Geneva, Switzerland or the nearest IEC Regional Centre.

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