3rd International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access

September 15-17, 2021

BOOK OF ABSTRACTS & PROGRAMME

Universitat de les Illes Balears
Palma de Mallorca, Spain

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Partner Organisations:

Organized by:

3rd International Conference on
Solar Technologies & Hybrid Mini Grids to improve energy access

Universitat de les Illes Balears
Palma de Mallorca, Spain

Solar Technologies & Hybrid Mini Grids to improve energy access

Conference Venue

University of Balearic Islands (UIB)
Carretera de Valldemossa
07122 Palma de Mallorca
Illes Balears, Spain

Date

September 15-17, 2021

Conference Chair

Dr. Carsten Hellpap
iiDev, Germany

Xavier Vallvé
Trama TecnoAmbiental, Spain

Organisation

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Solar Technologies & Hybrid Mini Grids to improve energy access

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Federal Office for the Environment FOEN

Swiss Federal Office of Energy SFOE

WISE
WATERLOO INSTITUTE FOR SUSTAINABLE ENERGY

MECS
Modern Energy Cooking Services

KIT
Karlsruhe Institute of Technology

And Supporting Organizations

Thank You Note

We welcome you to the

International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access

First of all, we would like to thank you all for following our invitation, and thereby contributing to the success of the conference.

A lot of successful work has already gone into the preparations for this International Conference, as clearly reflected in the huge response, for which we are much obliged.

Our warmest thanks to the conference chair **Xavier Vallvé and Dr. Carsten Hellpap** and the members of the scientific committee:

Prof. Peter Adelmann, Georg Bopp, Prof. Boaventura Cuamba, Prof. Bin-Juine Huang, Tatia Lemondzhava, Prof. Clark A. Miller, Dr. Andreu Moià, Prof. Jatin Nathwani, David Otieno, Kilian Reiche, Prof. Ricardo Rüther, Prof. Celestino Ruivo, Dr. Maria Ten Palomares, Werner Weiss and Tobias Zwirner for the great effort they have invested in the planning and realisation of the conference programme.

Thank you to all partner organizations, namely:

KIT, MECS, REPIC, Siemens Stiftung, SNV and WISE

We would like to thank our **sponsors** very much, namely:

EnDev, GIZ, Green People's Energy, CEGASA, EDP Renewables, SOCOMEC, Phaesun, STUDER and SUNLIGHT

Thank you also to all supporting organizations, namely:

ALER, Alliance for Rural Electrification, energypedia, GOGLA, HPNET, ISES, Solar Heat Europe, solarthermalworld and SUN-CONNECT

A big thank to all **speakers and poster presenters** for their contributions and particularly for the punctual delivery of their correctly formatted abstracts.

Your UIB Congress, Dr. Andreu Moià,
Xavier Vallvé, TTA,
Gabriele Struthoff-Müller, Ingo Vosseler
(Conference Managers) and all colleagues.

Conference Chair Message

Dear Colleagues,

On behalf of the Partner Organizations and the Scientific Committee, we are pleased to welcome you to the **third International Conference on Solar Technologies and Hybrid Mini-Grids to improve energy access, at the Unversitat de les Illes Balears in Palma, Spain on September 15-17, 2021**.

The main objective of the conference is to provide an opportunity for an exchange between practitioners from the industry, academia and development institutions working in the field of decentralized energy. The conference covers technical, business and management aspects of solar technologies and mini grids with the aim of sharing experiences, learning from each other and networking.

The spread of the COVID19 pandemic in forced us to urgently postpone this 3rd edition of the conference that was about to take place in April 2020. All the abstracts had been reviewed, the programme had been closed and most of us had already scheduled our attendance. A majority of the participants asked us to resume the conference in a face-to-face format when possible. As conditions to travel got better in many countries but not all of them, we had to compromise between waiting for a longer period of time or redesign it into a reduced hybrid format that allowed also online participation. We have taken on the challenge of this second option and the programme has had to be dynamically rearranged as participants confirmed their choices. Also the venue has had to be adapted to ensure safety to face to face participants and remote participation to those that have not been able to travel The effort by the conference secretariat has been intense and we appreciate your comprehension.

Solar technologies (including photovoltaic and solar thermal technologies) offer a unique opportunity to provide access to modern energies to more than 1 billion people in rural areas worldwide The pandemic has also provided lessons on the need to address development issues in a global perspective. Access to modern energy is an enabler and a necessity condition to improve the quality of life of households, to increase livelihood opportunities and productivity of enterprises and to professionalize the services of public institutions. However, access to energy should be embedded in cross-sectorial activities to achieve maximum impact. Thus, powering health centres and schools will only lead to better medical services and education if the necessary resources for appliances are available and proper management systems in place. Micro and small enterprises often invest in efficient equipment only if they have access to finance and to new markets. Solar crop drying or solar process heat can increase significantly the local added value of fresh produce. Mini-grids will transform rural communities if the full potential of the energy is used in the villages.

It is the intention of the conference to discuss the nexus of energy access with other sectors more in depth. The conference will also provide a forum to exchange experiences with the different business models in the field of solar technologies and mini-grids and innovative approaches. The conference will invite acknowledged experts to provide an overview about the status in different technology areas and give room to participants, which want to present their results from scientific research or experiences from the fieldwork.

We as chairs would be pleased to welcome you to the conference and encourage you to actively contribute to a successful event

Dr. Carsten Hellpap, iiDev, Germany
Xavier Vallvé, Trama TecnoAmbiental, Spain

CONFERENCE PROGRAMME

3rd International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access

September 15 – 17, 2021

Wednesday September 15, 13:00 - 16:30

SIDE EVENT:

Innovation Lab – Energy Access in A Crucible

Hosted by Affordable Energy for Humanity (AE4H)

Prof. Jatin Nathwani and Ambika Opal, WISE, Canada – ONLINE

The goal of the 'Innovation Lab' is *to develop and stress test a specific set of solutions for rapid implementation in the context of energy access in a disadvantaged community. We will rely on the divers, but, deep expertise that each participant brings to the lab. It is a dynamic learning platform that relies on a multi-disciplinary approach to provision of energy services for the very poor.*

We will draw on the strengths from the following:
technical and data analytical expertise,
economics and business models supporting micro-enterprises,
insights that inform social value of energy; its generative impacts and service value maps that address cultural preferences, needs of the young and the old and gender inequities.

WEDNESDAY, SEPTEMBER 15

16:00	**REGISTRATION OPEN**
17:00 17:35	**Opening Address** **17:00 – Xavier Vallvé,** Trama TecnoAmbiental (Spain) **17:05 – Dr. Andreu Moià,** Universitat de les Illes Balears (Spain) **Dra. Loren Carrasco**, Vicerectora d'Innovació i Transferència Digital. Universitat de les Illes Balears (Spain) **Keynote speech :** **17:15 – Jon Exel,** Team-Leader ESMAP, The World Bank (USA) - **Mini Grids for Half a Billion People, Two Years After Release of Main Report -** ONLINE

SESSION 1: PROGRESS AND CHALLENGES IN ACHIEVING SDG 7 **Chairs**: Dr. Carsten Hellpap, iiDEV, Germany Xavier Vallvé, Trama TecnoAmbiental, Spain	
17:35	**Solar – Thermal Systems as Solution to the Power Crisis in Southern Africa** Werner Weiss - AEE Institute for Sustainable Technologies (Austria) – ONLINE
17:50	**Experiences of Cooking on Solar Mini Grids** Melinda Barnard-Tallier & Dr Richard Seiff - Gamos - Loughborough University - University of Surrey (United Kingdom)
18:05	**Status of the Global Off-Grid Solar Market** Drew Corbyn - GOGLA (The Netherlands) - ONLINE
18:20	**SDG7: Status of Achievements of Energy Access for All, and the Role of Mini Grids in Reaching Universal Electrification** Tatia Lemondzhava - The World Bank (USA) - ONLINE
18:35	**Discussion**
INDUSTRY FORUM – Company presentations **Session organizer:** Ingo Vosseler, TTA, Spain	
18:50	• **Cegasa, Spain** • **Socomec, France** • **Studer, Switzerland** • **Sunlight, Greece** • **Phaesun, Germany -** ONLINE
19:15	**Welcome Reception and networking** 
20:00	**End of the First Conference Day**

THURSDAY, SEPTEMBER 16

9:00 - 9:15	**SESSION 2: ANNOUNCEMENT OF CONTINUOUS POSTER VIEW** **Organizer:** Dr. Andreu Moià-Pol, Universitat de les Illes Balears UIB, Spain Posters will be continuously available virtually on the App Padlet. On-site poster presentation during coffee-breaks and lunch.
A: SMALL PV and MINI-GRIDS	
Optimizer - Based PV Systems under Shading Conditions Virginia Cebollada Alvarez - University of Gävle (Sweden)	
Holistic microgrid planning for rural electrification Marina Petrelli - Politecnico di Milano (Italy)	
Comparative Assessment of Off - Grid Solar Photovoltaic (PV) System: Technical & Investment Analysis Dr. Abdul Muhaimin Mahmud - Public Works Department of Malaysia (Malaysia) - ONLINE	
Implementing Quality Criteria in Mini - Grids – Best Practices and Lessons Learned Tim Malzfeld - SMA Sunbelt Energy GmbH (Germany)	
Networked Rural Electrification Daniel Zimmerle - Colorado State University (USA)	
GIS Approach for Rural Electrification Silvia Corigliano - Politecnico di Milano (Italy)	
Blockchain vs DAG for Small Energy Community Pere Sabater - University of Balearic Islands (Spain)	
Using Blockchain to Incentivize Small Scale Power Trading and Mini - Grid Creation Michele Velenderic - Green Power Brains (Germany) - ONLINE	
The EnerSHelF Project Inter - and Transdisziplinary Research on Energy Supply for Health Facilities in Ghana Stefanie Meilinger - IZNE (Germany) - ONLINE	

The Role of Renewable Energy Off - Grid Systems in Global Electrification Scenarios and for Climate Action Dr. Philipp Blechinger - Reiner Lemoine Institut (Germany) - ONLINE
Off - Grid Hybrid Renewable Electricity Systems (OHRES) Deployment, Techno - Economic Modelling and System Data Analysis Platform Using Hybrid Battery Storage. Shared Experience from First Case - Study System Deployment in Nemiah Valley, BC, Canada Mohamed M. Elkadragy - Karlsruhe Institute of Technology (KIT) (Germany) - ONLINE
B: SOLAR THERMAL AND COOKING SYSTEMS
Monitoring Results of Solar Thermal Systems in the South African Region Rudolf Moschik - AEE INTEC (Austria) – ONLINE
The Use of Composite Heating Storage Materials Based on Zn(NO3)2·6H2O for Space Heating and Domestic Hot Water Supply in the Arctic Region of the Russian Federation Testov Dmitriy - Dubna State University (Russia) – ONLINE
Heating Storage Materials Based on MgNO3*6H2O Artem Morzhikhim Martovich - Dubna State University (Russia) – ONLINE
Refrigeration Appliances for Mini Grids: Options to Keep Energy Consumption under Control Dr. Victor Torres-Toledo - Phaesun GmbH (Germany) – ONLINE
Proposals to Cooperation in Overcoming Poverty and Lack of Prospects in Developing Countries by Open Source Appropriate Technology (OSAT) and Horticulture and Using Revenues from the Voluntary Compensation of Greenhouse Gas Emissions Manolo Vilchez - alSol (Spain)
C: CAPACITY BUILDING
Human Capital Development in Higher Education: a Long - Term, Integrated Approach for Achieving SDG7 Jiska de Groot - University of Cape Town (South Africa) - ONLINE
Capacity Building in Developing Regions Matthias Raab - SRH Hochschule, Berlin (Germany) - ONLINE
Innovation Diplomacy as a Driver of the Energy Transition Vitoria Elisa Silva - Federal University Of Uberlandia (Brazil) – ONLINE

SESSION 3: LESSONS LEARNED: FAILURE AND SUCCESS FACTORS

Chairs: Dr. Carsten Hellpap, iiDEV, Germany
Hedi Feibel, Skat Foundation, Switzerland - ONLINE

9:15	**Lessons Learnt from Pico PV, SHS, PAYGO Market Development; The Case of Kenya** Merijn Havinga – SNV (The Netherlands) – ONLINE
9:30	**African villages electrification** Marc Guirguirian – Socomec (France)
9:45	**Success of Self – Sustainable Off – Grid Rural Electrification Projects in India** Prasad Kulkarni – Gram Oorja Solutions Private Limited (India) – ONLINE
10:00	**Assessment of electrification options for off - grid areas in Cambodia** Andrés González García – Senergiality, S.L (Spain)
10:15	**Discussion**
10:30-11:00	**Coffee Break and networking**

SESSION 4: KNOWLEDGE TRANSFER, OPTIMISATION AND REGULATORY FRAMEWORK **Chairs:** Werner Weiss, AEE - Institute for Sustainable Technologies, Austria – ONLINE Dr. Andreu Moià-Pol, Universitat de les Illes Balears UIB, Spain	
11:00	**Global ONLINE Knowledge Management on Energy Access via Energypedia** Ranisha Basnet – Energypedia - ONLINE
11:10	**Battery Training for PV - Hybrid and Mini - Grid: A real Tool to Optimize the Projects** Claude Campion - 3C Projects (France)
11:20	**Promoting Solar Cooling through Technical Training Courses** Julian Krüger - Solar Cooling Engineering UG (Germany) - ONLINE
11:30	**Discussion**
11:40	**Potential Energy Savings in Interconnected Domestic Solar Systems** Daniel Zimmerle - Colorado State University (USA)
11:50	**Optimal Integration of Photovoltaics in Micro - Grids that are Dominated by Diesel Power Plants** Nils Reiners - Institute for Solar Energy Systems (Germany) - ONLINE
12:00	**Interactive Multicriteria Optimizer for Designing Microgrid Wind - PV Electrification Systems Considering Managements Constraints** Marc Juanpera Gallel - Universitat Politècnica de Catalunya (Spain)
12:10	**Discussion**
12:20	**Quality Assurance Framework for Component Based Solar Home Systems in Uganda** Geoff Stapleton - Global Sustainable Energy Solutions Pty Ltd (Australia) - ONLINE

12:30	**Adoption of Solar Water Pumps in Tanzania: The Farmers' Perspectives** Reinhard P. de Lucas Murillo de la Cueva - Instituto Superior Técnico, Universidade de Lisboa (Portugal) - ONLINE
12:40	**Isla Huapi: Setting up a Sustainable Business Model for Stand - Alone PV** Elena Villanueva Méndez - Ministry of Energy Chile (Chile) - ONLINE
12:50	**Discussion**
13:00	**LUNCH and networking** 

SESSION 5: DEVELOPMENT TRENDS IN THE OFF-GRID SECTOR **Chair:**, Daniel Zimmerle - State University of Colorado, US Tatia Lemondzhava - The World Bank (US) - ONLINE	
14:30	**An Integrated Approach for Powering Primary Health Facilities in Developing Countries with Solar Technologies** Carsten Hellpap - iiDev (Germany)
14:45	**Hydro Empowerment Network HPNET: What the solar mini grid sector can learn from more than 40 years of small-scale hydro experience** Dr. Hedi Feibel - SKAT Foundation (Switzerland) - ONLINE
15:00	**Haiti Renewable Energy Mini grid Program: PHARES** Georgios Xenakis – TTA (Spain)
15:15	**A History of Least Cost Mini Grid Design** Peter Lilienthal - HOMER Energy (USA) - ONLINE
15:30	**Discussion**

15:45 16:20	**Coffee Break and networking**

SESSION 6: INNOVATIONS, PRODUCTIVE USES AND PLANNING **Chairs:** Andrés González García, Universal Energy Access Laboratory - MIT & Comillas University, Spain Jatin Nathwani, WISE, Canada - ONLINE	
16:20	**How to Design a Photovoltaic Powered Aeration System** Petross Guambe - Songo Higher Polytechnic Institute (Mozambique)
16:30	**REvivED Water: Innovative Electrodialysis Solutions for Clean Drinking Water in Off - Grid Areas** Géraldine Quelle - REvivED water, Phaesun GmbH (Germany) – ONLINE
16:40	**Designing Solar PV for Topping up Energy of an Oil Based Solar Thermal Collector for Cooking Application** Tomas Nhabetse - Eduardo Mondlane University (Mozambique) – ONLINE
16:50	**Peltier Cooling in SHS systems** Daniel Goldbach - Fosera Solarsystems (Germany)
17:00	**MIA - Made in Africa** Prof. Peter Adelmann - id-eee Institute (Germany) - ONLINE
17:10	**Discussion**
17:20	**Smart Solar Off - Grid in Belize** Sarah Link - cdw Stiftung GmbH (Germany) - ONLINE
17:30	**Solar Cooling Systems for Agricultural Value Chains** Dr. Victor Torres Toledo - University of Hohenheim (Germany) - ONLINE

17:40	**Reliability Evaluation of Mini - Grids Considering Protection Issues** Maël Riou - Entech Smart Energies (France) - ONLINE
17:50	**Discussion**
18:00	**Development of a Monitoring and Evaluation Framework to Generate Data - Driven Load Profiles for Rural Households Powered by a Solar Hybrid Mini - Grid** Babak Ravanbach – DLR Institute of Networked Energy Systems (Germany) – ONLINE
18:10	**Exploring the Nexus of Mini - Grids and Digital Technologies** Dr. Bernhard Brand – Enerpirica (Germany)
18:20	**Interdisciplinary Analysis of Renewable Energy - Based Mini - Grids in Namibian Remote Areas – An Overview on the PROCEED Project** Sven Kühnel - Institute of new Energy Systems, THI (Germany) - ONLINE
18:30	**Discussion**
19:15	**End of the Conference Day** *Buses to the dinner restaurant are leaving in front of the University*
20:00	**Conference Dinner**

FRIDAY, SEPTEMBER 17

<table>
<tr><td colspan="2">

SESSION 7: ENERGY FOR LOCAL DEVELOPMENT AND LIVELIHOOD
Chairs: Dr Richard Seiff, MECS, UK
Catoer Wibowo, EnDev, Germany – ONLINE

</td></tr>
<tr><td>09:00</td><td>Hybrid Mini - Grids for Healthcare and Livelihoods Opportunities in Humanitarian Settings: The Case of Mahama Refugee Camp
Philip Sandwell - Imperial College London (United Kingdom) - ONLINE</td></tr>
<tr><td>09:15</td><td>Pay - as - you - go Solar: UGANDA - A Potential Energy Reality in the West Nile Humanitarian Context?
Cecilia Ragazzi - Mercy Corps (United Kingdom) - ONLINE</td></tr>
<tr><td>09:30</td><td>Study of Photovoltaic Energy for the Reduction of Moroccan Households Energy Poverty
Andreu Moià Pol - University of Balearic Islands (Spain)</td></tr>
<tr><td>09:45</td><td>Renewable Energy in Humanitarian Settings: a Blueprint
Aakarshan Vaid, IRENA (Germany) - ONLINE</td></tr>
<tr><td>10:00</td><td>Discussion</td></tr>
<tr><td colspan="2">SESSION 8: PANEL DISCUSSIONS
Session organizer: Xavier Vallvé, TTA, Spain
Kilian Reiche, iiDev, Germany – ONLINE</td></tr>
<tr><td>10:15</td><td>Topic 1: Touch Safe Rural Electrification
Participants: Dan Zimmerle, Pablo Muñoz, Maël Riou</td></tr>
<tr><td>10:35</td><td>Topic 2: Pros and Cons in Subsidy schemes for energy access
Participants: Carsten Hellpap, Georgios Xenakis, Hedi Feibel</td></tr>
<tr><td>10:55</td><td>Topic 3: Trends in thermal applications driven by solar energy
Participants: Werner Weiss, Simon Batchelor, Victor Martínez</td></tr>
<tr><td>11:15-
11:45</td><td>Coffee Break and networking </td></tr>
</table>

SESSION 9: INTEGRATED CONCEPTS AND ENERGY MANAGEMENT **Chairs:** Xavier Vallvé, TTA, Spain Kilian Reiche, iiDev, Germany - ONLINE	
11:45	**Promoting Sustainable Communities via Appropriately Designed and Participatory Energy Access in Rural Areas of Developing Countries** Davi Ezequiel Francois - ITAS & KIT (Germany) - ONLINE
12:00	**Integration of Electro - Mobility Solutions into Off - Grid PV Systems for Sustainable Development of Rural Areas in Sub - Sahara Africa** Aminu Bugaje - Institute of new Energy Systems, THI (Germany)
12:15	**Gender Mainstreaming in Solar Irrigation projects** Ranisha Basnet - Energypedia UG/Albert-Ludwigs-Universität Freiburg (Germany) - ONLINE
12:30	**Energy Management in Offgrid Systems** Pierre-Olivier Moix - Studer-Innotec (Switzerland)
12:45	**Results Based Financing to Catalyze Commercial Finance for Off-grid Solar Market Development** Martijn Veen, SNV (The Netherlands) - ONLINE
13:00	**Discussion**
13:30	**CLOSING REMARKS** Dr. Carsten Hellpap - iiDev (Germany) Xavier Vallvé - Trama TecnoAmbiental (Spain) **END OF THE CONFERENCE**

"SOLAR LUNCH"

September 17, 13:45 (lunchtime networking)

Manolo Vilchez and Julio Cantos lead a Solar Cooking Event. Participants are encouraged to get involved, enjoy the meal and have fun together!

ABSTRACTS

SESSION 1

PROGRESS AND CHALLENGES IN ACHIEVING SDG 7

WEDNESDAY, September 15

Solar Thermal Systems as Solution to the Power Crisis in southern Africa

Werner Weiss
AEE – Institute for Sustainable Technologies
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E-mail: w.weiss@aee.at
Website: http://www.aee-intec.at/
Keywords: Solar Thermal, Training, Demonstration Systems, Monitoring, Roadmaps and Implementation Plans

Training and Demonstration Systems

Countries in Southern Africa suffer massive electricity shortages and regular power cuts for years. A significant part of electricity is currently being converted into low-temperature heat. To solve this problem and to exploit the huge solar thermal potential, seven research institutes and universities from Austria, Botswana, Lesotho, Mozambique, Namibia, South Africa, and Zimbabwe as well as local solar companies co-operate since 2009 in the SOLTRAIN project.

Up to now, 3,000 people have been trained in 110 training courses, and the lessons learned in the courses have been implemented by local companies in 326 demonstration projects. The installed solar thermal systems span the range from small plants with 2 m² collector area for hot water preparation for single-family homes to systems that supply industrial processes with up to 600 m² collector area. In 2018, the two largest solar thermal systems in Sub-Sahara Africa were built in the course of this project. The annual solar yield of all the plants installed since 2009 adds up to 3,533 MWh and CO_2 savings of 1,222 tons.

Monitoring

To prove the performance and reliability of the solar thermal systems for users as well as for political decision makers, 29 of the solar thermal systems were equipped with monitoring devices in order to measure solar yields and to evaluate the performance of the systems in detail. All these systems are equipped with heat meters, a data logger, radiation sensors and temperature sensors.

The systems were monitored for 12 months. They show specific annual solar yields between 516 kWh/m² and 823 kWh/m². This proves the excellent performance of these systems.

Fig. 1: The size of the demonstration plants installed in the course of the project ranges from 2m² to 600m² collector area

Solar Thermal Roadmaps and Implementation Plans

In order to support broad roll out programmes of solar thermal systems in all six participating countries Solar Thermal Roadmaps and Implementation Plans were developed in broad stakeholder processes in close cooperation with policy. Last but not least - an extensive program to support students in their master's thesis completes the project.

Experiences of cooking on solar mini grids

Dr Simon Batchelor
Dr Jon Leary, Prof Ed Brown, Prof M Leach
Gamos/Loughborough University/University of Surrey
Epinal Way
Loughborough
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E-mail: research@gamos.org
Website: www.mecs.org.uk
Keywords: Electric pressure cooker, solar PV, mini grids, Tanzania, Myanmar, Kenya

As the cost of solar PV and energy storage continue to reduce, it has become viable to consider utilizing the excess energy production of Solar PV based mini grids to offer a cooking service. This depends on utilizing various mechanisms, smart meters, tariff differentials, etc., to stimulate user behavior and load management that fits with the mini grid development. Indeed, careful utilization of cooking loads can actually enhance the profitability of the mini grid.

The paper presents experiences to date in Myanmar, Tanzania and Kenya (2017 to 2019). Early piloting and testing of possibilities of adding cooking to mini grids. It draws on several years work on how people cook and their energy use, identifies efficient appliances, and matches the appliance consumption to the mini grid capacity. Techno economic modelling illustrates how the use of the cooking can enhance the profitability of the grid, while offering the households a clean cooking solution that mitigates the harmful health effects of biomass based cooking, addresses environmental and deforestation concerns and contributes to better quality of life for women including more opportunity for income generation.

The paper will cover the technical advantages of certain energy efficient appliances, the matching of the appliance to the socio cultural needs of the people, the techno economic modelling that provides a foundation for developers to decide the value of the proposition, and the effect on tariff charges and timing on the take up of the propositions.

Status of the Global Off-Grid Solar Market

Drew Corbyn
GOGLA
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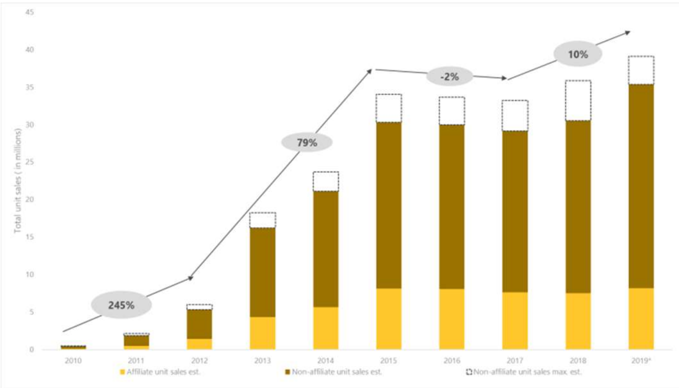
Website: www.gogla.org
Keywords: off-grid solar

The size of the off-grid solar market

The off-grid solar market has grown tremendously over the past 10 years into a vibrant US$ 1.75 billion market serving 420 million users, and remains on a solid growth curve.



Global estimates of annual unit sales of off-grid solar products by segment (2010–2019)[1]

The sector accelerated rapidly between 2010 and 2015, followed by a dip in 2016-17 due to localised shocks (such as demonetisation in India and drought in east Africa) and companies adaptations in response to sector-wide trends such as commoditization of entry-level products and the saturation of easy-to-reach markets.

[1] Off-grid Solar Market Trends Report 2020. Lighting Global, GOGLA and ESMAP. Published: February 2020.
Affiliate products are sold by companies that are connected to any of the partner organizations involved in the semi-annual GOGLA sales data reporting process. There is much less data on the non-affiliate portion of the market, though it contributes significantly to sales volumes

Sales of affiliate products in 2019 are expected to exceed eight million units; of which 69% are solar lanterns, 15% are multi-light systems, and 17% are Solar Home Systems (SHS). This represents about 80MW of new installed capacity globally. There is a shift towards larger products with more functionality and greater performance and for sales by PAYGo (pay-as-you-go), an innovation that has dramatically enhanced consumer affordability.

Kenya and India remain the biggest single country markets and there are numerous other countries such as Ethiopia, Zambia, Nigeria and Papua New Guinea where the market is flourishing.

Technology trends and innovation

The cost of manufacturing off-grid solar products continues to decline; largely driven by leveraging advancements and efficiencies from larger industries, namely the PV power market and lithium batteries for electric vehicles. Lithium-ion batteries now dominate the off-grid solar sector (though lead-acid batteries remain in use for larger systems) thanks to improvements in performance, longevity and cost; the design of leading SHS kit battery is now around 2500 cycles[2] – giving five to seven years' service.

Digital innovation is the new frontier. Connected devices and the Internet of Things have introduced powerful possibilities, for example battery monitoring can identify if the PV panel needs cleaning and send an automated message to advise the owner. Likewise, it can predict when the battery needs replacement and inform the company's spare parts inventory. At the fleet level, data analytics is helping companies to optimise component and system design. Artificial intelligence is now being used to help companies assess potential consumers' ability to pay and enhance product performance, while satellite mapping technology is able to identify new sales regions with a high potential customer base.

This session will present market trends and showcase technological innovations in the off-grid solar market.

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SESSION 2

ANNOUNCEMENT OF CONTINUOUS POSTER VIEW

WEDNESDAY, September 15

Optimizer-based PV systems under shading conditions

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Keywords: *Solar PV, Shading, Power optimizers, MPPT*

Introduction

Recent decrease in the cost of photovoltaic (PV) panels [1] and the increased average residential PV size in Sweden [2] has caused larger residential roof-top PV installations to become more popular. This implies they might be mounted on roof segments with different orientation. Additionally, with larger installation size the likelihood of having partial shading increases. Thus it is expectable to have varying irradiation conditions on different parts of the PV system.

Total or partial shading conditions (PSC) have a detrimental impact on the output energy of PV systems. Shade causes a reduction of the power delivered. Traditional string PV systems work with one or two central Maximum Power Point Tracking (MPPT) for the entire system, which means that when they undergo PSC, the overall system's production is limited by the solar panel providing the minimum output.

An effective solution to mitigate the shading effect is the use of power optimizers. These devices act at module level with the individual MPPT's, which leads to better PV system performance in comparison to a string-based system [3]. The electrical configuration of both systems is shown in Figure 1.

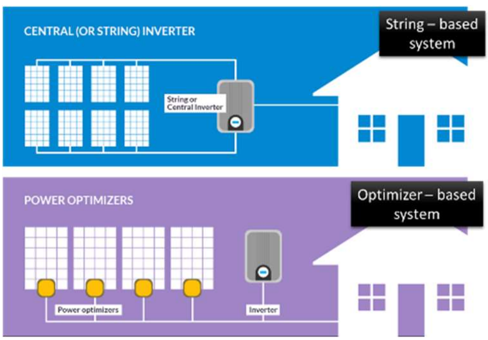

Figure 1: String-based PV system with central MPPT for entire system and optimizer-based PV system with individual MPPT for each panel

Procedure

To quantify the gains with power optimizers, measurements and experimental setups were carried out at Vattenfall laboratory (Sweden) to investigate production gains under shading conditions that are realistic for small homes. This study evaluates the performance of two PV systems with different power conversion setups: a 3.3 kW_p PV array from 2017 connected to a Fronius string inverter and a 2018 4.3 kW_p array connected with SolarEdge optimizers and inverter. The solar panels are of compatible STC ratings. Experiments were performed to verify the optimal orientation of the arrays and their performance under simulated snow coverage and tree shading.

The PV production of both systems was measured for East and South orientation to verify their optimal configuration. The simulated snow coverage experiment used semi-transparent mesh attached to the bottom row of both systems covering up to 60% of each module (*Figure 2*). With the aim to recreate a more realistic shading pattern a pine tree is placed directly south of the arrays (*Figure 2*), simulating the shade projected by neighboring trees on residential PV installations.

Figure 2: Experimental setup with simulated snow coverage (left) and for the tree shading experiment (right)

Results and conclusion

Findings demonstrated that the output achieved with South orientation was 30-36% higher than East-oriented. Shading losses with optimisers were reduced from 50% to 29% on clear May days when simulated snow coverage is applied (*Figure 3*). Results also showed that optimizers decreased tree shading losses from 24% to 9% with differing irradiance over two weeks in June (*Figure 3*). This full measurement period of two weeks with varying cloud coverage confirmed that these gains are obtained also under longer periods.

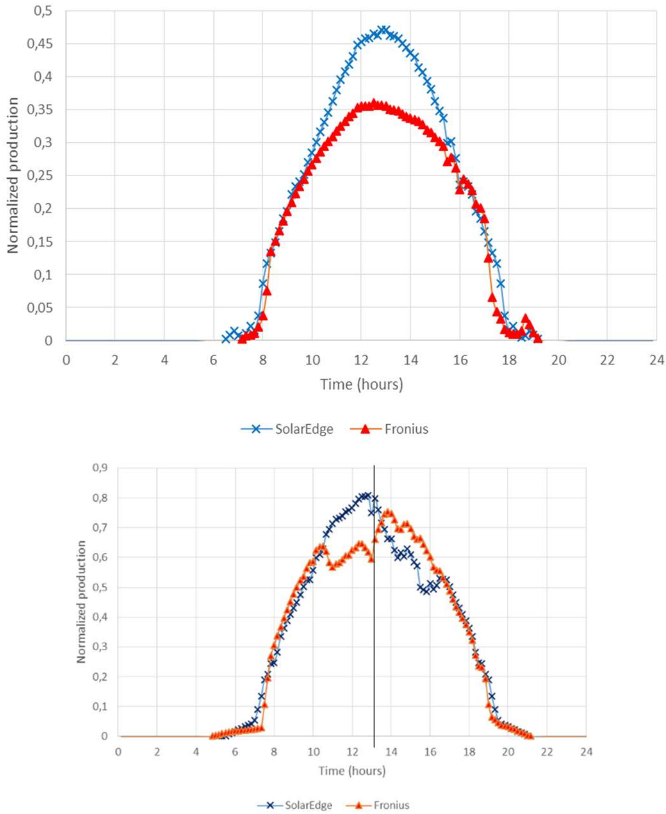

Figure 3: Normalized production of both systems under fabric mesh shading (left) and tree shading (right)

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Holistic microgrid planning for rural electrification

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Keywords: microgrid, optimization, rural electrification, multi-year planning, multi-disciplinary studies

Subtitle

An extensive adoption of isolated microgrids is crucial to reach universal access to electricity by 2030, complying with the Sustainable Development Goals set by the United Nations. Effective rural electrification programs require the use of comprehensive computer tools, able to capture the complexity and the dynamics involved in such projects. Standard microgrid planning optimization algorithms identify the least-cost solution and its corresponding optimal design and operation of the plant. These tools are extremely important in supporting decision makers and in overcoming traditional sizing methods, which fail to provide accurate and efficient indications. However, the state of the art does not fulfil the need of a thorough and exhaustive analysis and often neglects crucial aspects that significantly impact the outcome of the project in the long run.

This work develops a holistic MILP microgrid planning tool that allows decision makers to accurately evaluate the different options and select the most suitable and long-lasting solution. In particular, the multi-year characteristics of the system are modelled, namely asset degradation and demand growth. An iterative procedure is adopted to effectively describe the non-linear phenomenon of storage capacity reduction, related to the hourly scheduling of resources, within the MILP framework.

The outcome of a project is closely linked to the socio-economic dynamics that are triggered after the first installation; these can lead to very different overall behaviours and considerably weigh on the effectiveness of the system. This long-term uncertainty is tackled by means of a stochastic optimization evaluating different load scenarios and identifying the best compromise solution, ensuring feasibility and reliability of the service under any realization of the inputs. In order to reduce risks and adapt the configuration of the system to the actual load trends in time, the installation of components is not limited to the outset of the project, it can be integrated through subsequent capacity expansions, tailored on the pertaining scenario.

Rural electrification studies are often focused on the identification of the least-cost solution; hence, cost is usually the only decision criterion adopted. Recent attention to environmental issues has pushed some researchers to also include environmental indicators. Social impacts are rarely assessed, although they strongly contribute to determining the effectiveness of rural electrification actions. In this work, a multi-objective optimization is used to extend the decision-making process and evaluate the trade-offs between economic, environmental and social objective functions. A novel algorithm is proposed to reduce the computational burden and significantly improve traditional multi-objective methods.

Therefore, this work presents a comprehensive model for rural microgrid planning, whose performances are tested on the case study of an isolated community in Uganda.

Comparative assessment of off-grid solar photovoltaic (PV) system: Technical & investment analysis

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Keywords: Solar PV hybrid system (SPVHS), Integrated Solar PV system (ISPV), off-grid, lifetime cost

This paper demonstrates the type of solar Photovoltaic (PV) system and technology for off-grid Rural Electrification Program (REP) in Malaysia. Centralized off-grid solar PV system, normally referred to as Solar PV Hybrid System (SPVHS) is widely implemented by several REP initiatives. Even though SPVHS is considered successfully implemented for REP in rural Malaysia, several issues arise such as reliability of power supply, environmental issue, land requirement and lifetime cost. Thus, this study introduces Integrated Solar PV system (ISPV) to compliment the gap created by SPVHS. Comparative analysis on technical and economy was conducted on both systems. Technically, ISPV shows advantages as compared to the SPVHS. ISPV system is more reliable in providing daily energy required, environmentally friendly that the CO_2 emission reduces by 68% and efficient energy storage system. Furthermore, ISPV creates community involvement that part of the system operation is operated by the community. This model can guarantee sustainability of the REP. The project owner, in this case the Government can save 47% of project lifetime cost compared to the cost to implement SPVHS. Therefore, based on the explanations and analysis provided in this report, it is recommended that ISPV to be considered as future off-grid solar PV system.

Implementing quality criteria in Mini-Grids – Best practices and lessons learned

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Keywords: Mini-Grids, Quality, Investment security

How to ensure system sustainability in remote regions?

The market for Mini-Grids is growing worldwide based on mature technologies available, decreasing system cost and continuous support from development banks as well as private investors. Individual projects get bigger and bigger and more and more governments integrate Mini-Grids and Rural Electrification Programs into their political agenda.

But how to ensure proper system operation even years after installation and commissioning as well as system sustainability in remote regions with improper infrastructure and unclear responsibilities in terms of O&M? How to ensure investment security to investors? Indeed, even though Solar Mini-Grids require less maintenance than e.g. Diesel Genset systems, there are still systems being installed which are not working properly after some time and end up as 'stranded assets', because either the system planning has been not adequate, or the installation is not carried out professionally, or there has not been implemented any proper Service and O&M concept.

This presentation highlights quality aspects along the entire project value chain based on real-life project examples, from system design to choosing and installing of components up to implementing a well-designed know-how transfer and training concept for local O&M staff.

Example 1: Island electrification (St. Eustatius) with 4.1 MWp PV plus 6 MWh Li-ion battery storage

Example 2: Off-Grid system for tourist resort in Tanzania with 130 kWp and 900 kWh lead-acid battery storage.

Networked Rural Electrification

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Keywords: Rural electrification, A* algorithm, minimum spanning tree, optimal network

While mature technologies are available for providing electricity to off-grid villages, correct capacity planning remains challenging. A single village is geographically so small that large-area resources statistics (i.e. solar radiation / wind) cannot be used as a reliable predictor of power generation. Historical demand records are typically unavailable and highly variable due to the small number of users. Load growth / decline is also uncertain because population and activities of the village can change substantially. Finally, the location of villages was historically determined by access to water, soil, storage, etc., rather than access to rich solar or wind resources. As a result, generation resources within each individual village are often substantially less than the overall regional resource availability.

These issues can be mitigated if villages in a region are linked together via an optimally an electrical network which connects a few resources-rich centralized generation sites to the region's villages. Each village is supplied by (a) the centralized generation sites, and (b) flexible generation in the village that can be added or removed depending upon demand. Viability of this approach is determined by the cost of building such a network. Two design stages are: (i) finding near-optimal connection paths village-to-village and village network-to-generation sites, and (ii) selecting the appropriate paths to form the optimal network.

The A* algorithm is widely used to search for optimal paths. However, for this problem the A* search is computationally inefficient due to substantial, but smooth, topographical variation in a region, which differs substantially to routing problems where A* is typically deployed. In this work, the authors expand on previous developments of an modified A* algorithm, the "multipler-accelerated A* (MAA*) algorithm," which generally reduces computation time by 80-90% while sacrificing <10% of optimality. This paper illustrates optimal network design by applying MAA* in conjunction with minimum spanning tree (MST) method. It will also be demonstrated that this approach offers flexibility for changing network design according to practical constraints identified during project implementation.

GIS approach for rural electrification

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Keywords: *Rural electrification, Sustainable Development, GIS data, grid topology*

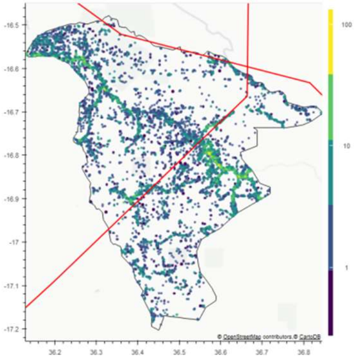
Geographical Information System (GIS) data are gaining importance in the field of rural electrification. Modern tools exploit the potential of georeferenced information to study the optimal electrification strategy in wide areas, choosing among centralized and decentralized solutions [1], [2], [3]. However, the tools are often very generic and use simplified assumptions to deal with a huge quantity of data.

The authors propose a holistic geospatial based procedure that overcomes the limit of available literature, by autonomously performing electric network design processes and optimal energy strategy planning.

The proposed procedure is composed by different steps, it allows to design the optimal distribution grid topology in non-electrified rural areas and to define the best solution among connection to the national grid, microgrid installation or electrification with off-grid systems. The procedure has been coded in Python and tested with the real case study of Namanjavira province, in Mozambique, thanks to the collaboration with the ngo COSV.

Chosen a defined case study area, GIS based data, related to energy resources, load distribution and terrain characteristics are collected and combined together. The territory is subdivided into a regular grid of points, at a distance equal to the desired resolution, and to each point are assigned all the characteristics relative to its location (e.g. population, elevation, distance from road). The information is useful to identify a weighting factor, which represents the cost of connecting each point with electric grid lines, e.g. points on rivers, mountains or situated in thick forests have a higher penalty cost The population density in each location can be used as a proxy indicator of the geographical distribution and intensity of the future energy demand. The **spatial clustering** algorithm **DBSCAN** is applied to identify areas (clusters) with higher population density and sparse populated locations (outliers). The outliers are locations that are suited to be electrified with off grid systems.

LoadProGen tool and Homer are then used to respectively find the energy demand of each cluster and the optimal microgrid size [4].



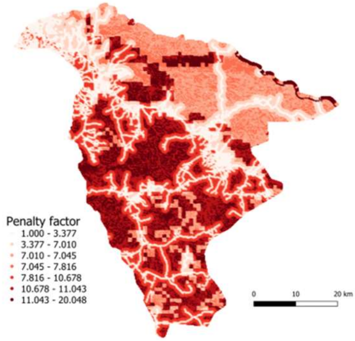
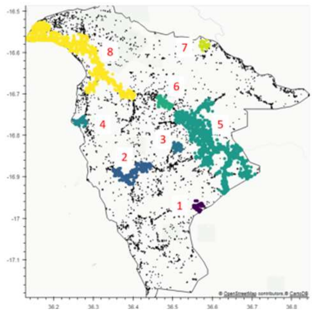


Figure 4 Population distribution in Namanjavira

Figure 5 Penalty factor distribution in Namanjavira

The **optimal distribution grid topology** is designed for each cluster, using graph theory algorithms. An innovative procedure, which is a combination of **Kruskal** and **Dijkstra** algorithms, is used to connect populated points passing by convenient routes, such as roads, and avoiding difficult paths. The connection cost of each cluster to the nearest national grid primary substation is also evaluated.

As a final step, the LCOE of microgrid, comprehensive of the distribution grid cost, is compared to LCOE of national grid connection and the best electrification solution, the one with lowest cost, can be defined.



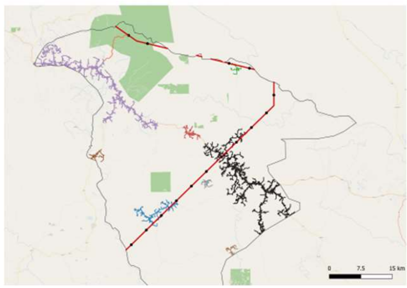


Figure 6 Clustering process

Figure 7 Grid routing output

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Blockchain vs DAG for small energy community

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1. INTRODUCTION

Energy has become a socially worrying topic, due to the economic fluctuations and complicated legislation, in countries where clear legislation is often a very important brake on policies for the implementation of renewables. If we also take into account that climate change is one of the most worrying problems for many countries, and that in many cases it is very difficult for the public administration to involve private companies and individuals in mitigation and the implementation of measures. Often the legislation itself is not enough or comes into contradiction in certain aspects that prevent a greater degree of implementation.

2. DESCRIPTION

The proposed solution consists of a plurality of buildings (residential or services) of a population or an isolated interconnected nucleus forming a micro-network of the necessary infrastructure services. The infrastructures are shared in the micro-network and have an external connection where there would be a cloud of micro-networks connected from the backbone network. This includes energy: electrical and thermal, telecommunications and water. For this, a management service is available, based on communications and DLT (Distributed Ledger Technology). Where each building would have the capacity of hosting a node to validate the transactions, each building would have a unified control system, as an electronic switchboard, with a logical partition for each infrastructure service. So that the plant would have a flow meter, a router, an electrical and thermal meter, and distributed databases.

The management of both technologies, blockchain or DAG architecture, would be unassisted and automated, so that a central computer to the micro-network could process statistics or manage the maintenance of the micro-network buildings of buildings. The system would be capable of pricing imports and exports of water (i.e., rainwater, Domestic Hot Water…), import and export of electric power from the micro generation of the building and the micro network connected to the external electrical network or Smart Grid.

While the bandwidth of the telecommunications network would be distributed, and assignments could be made to recover at posteriori. So, when a building needs to be self-sufficient in the micro-grid, it will involve a purchase or a sell. While when there is self-supply in the building the surplus can be sold or sold. In these infrastructures the municipal administration needs to be involved, since part of the infrastructure would run through public domain paths, so the town councils should be part of the exchange network.

Although the two options may be valid in this solution, a comparison of both is presented. To make the case more concrete, IOTA (Tangle – DAG) is going to be the DLT technology selected. Blockchain technology is suitable for scenarios in which it is required to store some data in increasing order, without the possibility of modification or revision and whose trust is intended to be distributed instead of residing in a certifying entity.

The most important feature about IOTA is the data structure used, known as DAG, is distributed among all nodes in the network. As in blockchain there is a consensus about the correct DAG. This DLT technology is focused on Internet of Things.

Figure 1 – Tangle (DAG) vs Blockchain data structure

Table 1 – Blockchain vs DLT (IOTA)

	Blockchain	DLT (IOTA)
Transaction fees	Yes	No
Transaction speed	Slow	Fast
Miners	Miners	No miners
Micro-transactions	Too expensive	Ideal
Scalability	Not scalable	Scalable

To sum up the best system is IOTA since is cheaper, faster, and ideal than blockchain for micro-transactions and scalable on the opposite blockchain is too expensive for micro-transactions, slower and not scalable..

Using Blockchain to incentivize small scale power trading and mini-grid creation

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Keywords: Blockchain, Distributed Ledger Technologies, Mini-Grid

It is estimated that about 12% of the world's population, more than 840 million people, have no access to electricity. In Sub-Saharan Africa this figure rises to roughly 55% of the population.[1] This electricity shortage has a negative impact on the economies of the area and on the welfare of the people affected.[2]

In addition to the electricity production itself, a big challenge is the distribution over vast, often scarcely-populated areas. High capital and operational expenditures and a lack of capacity for maintenance and operation, as well as undeveloped markets, are some of the problems that have to be faced when considering electrification in developing countries.

A decentralised energy production of mutually-independent off-grid, or grid-failover, hybrid power systems based on renewable energy sources bears various advantages. These are, among others, lower capital costs, less-complex installations and lower maintenance efforts that can be handled by local staff, as well as higher resilience in terms of technical failure.

In terms of service security however, independent renewable-energy-based power systems lack the advantages of a well-developed grid, overcapacities having to be installed in order to cover higher power demands during times of low renewable energy resources availability.

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[2] Electric Power and Natural Gas - Brighter Africa, Antonio Castellano et. al., McKinsey & Company, Feb. 2015

Connecting independent power systems into a mini-grid could solve this issue and is often technically feasible. When the connected systems have the same owner the only barrier might be of technical nature. Connecting power systems with different owners opens the same possibility for isolated power systems to evolve into interconnected mini-grids, where different power systems support each other. However, open questions on fair usage and the lack of tangible financial incentives prevent this kind of connections from becoming common practice.

The goal of this paper is to examine the potential of connecting autonomous, decentralised power systems based on peer-to-peer energy trading in developing countries. This approach combines the advantages of decentralized power systems with the service security of a power grid by connecting together single off-grid or grid-failover renewable-energy-based power systems. A promising technical approach is the introduction of a blockchain-based solution that facilitates a fully autonomous electricity trade between single users and owners of the power systems within the mini-grid by using smart contracts. Automatic payment, confirmation of operation status, dynamic pricing as well as flexible incentives for services are some of the advantages of a blockchain-based solution.

Most importantly, the low transaction costs enable even the smallest systems to be integrated into publicly-owned mini-grids, which strongly increases the value of each individual system.

This approach will highly incentivize private investments into power systems and will boost efforts to provide electricity to communities in developing countries.

The EnerSHelF Project Inter- and transdisziplinary research on Energy Supply for Health Facilities in Ghana

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As in many West-African countries, Ghana often experiences electricity grid instability as well as power outages. Both lead to considerable impairments in the health sector. Electricity from photovoltaic systems (PV) is a sustainable alternative, but the PV market in Ghana is largely untapped. The German-Ghanaian project EnerSHelf (brings together experts from science and practice from a wide range of disciplines who jointly develop technical and political-economic solutions for improving and disseminating marketable PV-based energy solutions for healthcare facilities in Ghana.

The EnerSHelF project (https://www.bmbf-client.de/en/projects/enershelf) builds on results and activities during the EnerSHelF Definition project which was conducted in 2017 to assess the on ground energy situation (availability and reliability) of health facilities of different types (CHPS up to teaching hospitals), with differing energy demands and sources, and at various rural and urban locations across Ghana.

The project design follows an inter- and transdisciplinary (engineering and development economics) approach. On the one hand the project focuses on developing, applying and evaluating technological solutions (case studies). On the other hand it addresses interdependencies between technology development, technology adoption & technology diffusion by embedding the development of technological solutions into the institutional and socio-economic context in Ghana (survey data analysis/ case studies).

Here we will present the project idea and first project results. A simulation model für a PV-hybrid-system is used to simulate the energy situation of a hospital in Ghana. The influence of different seasons and weather conditions on the PV yield and the entire system is investigated for the period from February 2016 to February 2017.

We used PV and load measurement data from a hospital in Akwatia, Ghana, as a model input. We also used the detected power outages registered in the data set. Using this data set, we investigated the influence of season and infrastructure (PV and battery size) on the operating mode of the system. We found, that especially during the rainy season in August the PV output decreases and consequently a lot of energy has to be provided by the public grid and the generator. Another significant decrease in PV yield is observed in January due to dust storms during the Harmattan season. The results have been published in Bebber et al., 2021 (https://doi.org/10.18418/978-3-96043-091-9).

The Role of Renewable Energy Off-Grid Systems in Global Electrification Scenarios and for Climate Action

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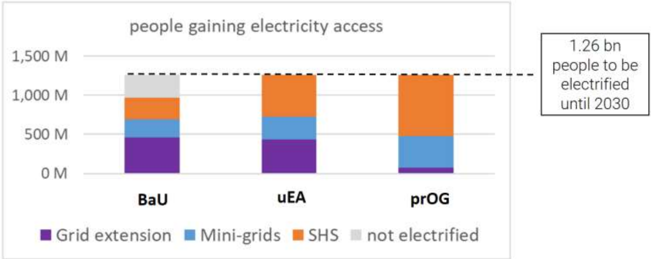
Keywords: SDG7; SDG13; energy access; off-grid; climate action

Context: In a global study, off-grid systems (mini-grids and solar-home-systems) are assessed regarding their importance for electrification and climate change mitigation and climate change adaptation. Particularly the impact of off-grid technologies for providing electricity access in 52 target countries with low electrification rates are quantified. Furthermore, market potential, related green house gas emission mitigation and the respective socio-economic benefits are analysed.

Main Results: Achieving universal electrification by 2030 (SDG7) implies the provision of electricity access to more than 1.2 billion people cumulatively, of which the majority characterizes as highly climate vulnerable. Based on the findings of this study, in most cases, off-grid renewable energy (OG-RE) technology has significant practical and economic merits over grid expansion.

In addition, OG-RE bears significant relevance for climate change mitigation and adaptation, having the potential to reduce GHG emissions; to build resilience towards adverse consequences of climate change on human and environmental systems, and; to provide pathways for green growth and development. In many regions of the world, SDG 7 can be reached cheaper, cleaner and smarter with OG-RE compared to a grid extension scenario.



BaU Scenario	uEA Scenario	prOG Scenario
• Focus on grid-extension • SDG7 not achieved	• Focus mix of off-grid and grid-extenstion • SDG7 achieved	• Strong focus on off-grid • SDG7 achieved

Figure 1: Scenarios for Electrification: Business as Usual, universal Energy Access, Progressive Off-Grid

Three electrification scenarios were developed for 52 target countries, which cover the electrification of more than 1.2 bn people until 2030.

• *Cheaper:* Electrification through off-grid systems requires less investments when compared to a grid-extension scenario. For a universal Energy Access (uEA scenario), initial investments of 380 bn USD are needed to supply all people with minimum needs. To improve livelihoods and productive use, 580 bn USD are needed (higher Tier case). A strong focus on off-grid (prOG scenario) would lead to investments of only 270 bn USD (lower Tier case) or 565 bn USD (higher Tier case).

• *Cleaner:* Electrification through off-grid systems saves more CO2 emissions when compared to a grid-extension scenario. Highest per capita emissions occur for people with no electricity access (using kerosene). Off-grid electrification have minor (mini-grids) or whwn using solar home systems (SHS) zero related GHG emissions. Cumulated GHG emissions savings (2017-2030) for the universal Energy Access (uEA scenario) range from 300 to 485 M tons. For off-grid (prOG scenario) the savings are considerably higer: from 450 M to 810 M tons compared to Business as Usual (BaU scenario).

• *Smarter:* Off-grid systems are comparably flexible and fast in installation. Off-grid systems can significantly improve livelihoods as they enable productive uses and community services. In addition, they create socio-economic benefits e.g. health, air pollution, education, communication, income, food security and overall strengthen the resilience towards climate change impacts.

Off-grid Hybrid renewable Electricity systems (OHRES) deployment, techno-economic modeling and system data analysis platform using hybrid battery storage.

Shared experience from first case-study system deployment in Nemiah Valley, BC, Canada

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Keywords: Off-Grid Hybrid Renewable Electricity Systems (OHRES), Hybrid Battery Storage system (Lithium-ion and Lead-acid), Hybrid Off-Grid Techno-economic Modelling (HOTEM), Off-Grid Systems Data Analysis Platform (OSDAP).

Offgrid hybrid renewable electricity systems (OHRES) is a major important player in the energy access global challenge. What we are investigating is how technical, economic, and environmental contexts influence the economic feasibility and sustainability of OHRES systems. Our methodology to achieve such objective is through carrying out a contrastive techno-economic analysis and system design optimization of two similar wind/solar OHRES systems installed in case-study locations with very different climatic and economic conditions - Canada and Uganda. These projects are carried out as part of the AE4H[1] global initiative.

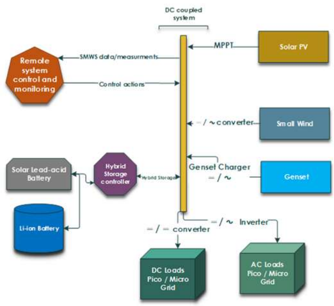

Figure 8 OHRES topology and main system components

1. OHRES first case-study system deployment in Canada

In this publication (which can be considered as following-up publication to our poster in the previous energy access conference), we will share the latest status of our first OHRES deployment in a household located in Nemiah Valley, BC, Canada. The hybrid system includes solar PV, small wind turbines as main renewable energy sources. In addition to dual-fuel genset as backup unit, and Hybrid lead-acid & Lithium-Ion (Li-ion) battery storage system with 48V DC coupling, which represents a unique and innovative

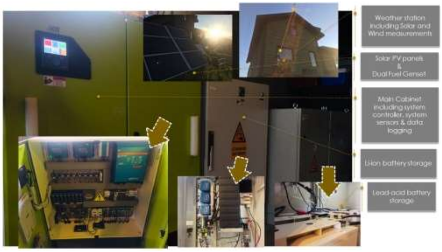

Figure 9 OHRES in Canada household case-study - System on ground commissioning

system structure as shown in figure 1. The system includes also system monitoring and weather station (SMWS), with full system remote monitoring and the ability of system selected components remote control. The case-study household in Canada is currently fully running on the OHRES as shown in figure 2, after one year of lab testing.

We will highlight the technical and economic benefit of having a hybrid lead-acid + Li-ion battery storage system for such application, using detailed techno-economic modeling results based on real system deployment costs for the Canada case study. Example of the technical joint force characteristics of both batteries can be seen in figure

2. Offgrid Systems Data Analysis Platform (OSDAP)

The second aspect is our OSDAP (figure 3), which is a Python-based tool developed to carry out performance analysis tasks on the OHRES operation data. This tool has been developed for one day or long-term performance analysis of PV, energy storage unit and overall system performance. The tool has been using the data generated from the already running OHRES in Canada, and it has been developed in a generic architecture so that it can also perform the performance analysis tasks on both case-studies OHRES, once they are deployed and starts operating.

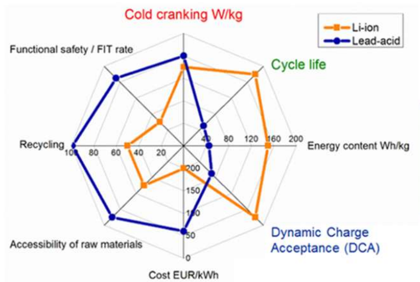

Figure 10 Li-ion and Lead-acid storages general joint forces characteristics[2].

An artificial neural networks based solar irradiance forecasting model has been developed to make one-hour ahead and 24-hours ahead solar irradiance forecasts. Long-short term memory (LSTM) model takes historical weather data from our weather station installed at the case study location in Canada and it yields one-hour ahead irradiance forecasts with RMSE value between 23 and 80, correlation coefficient range between 95% and 99%.

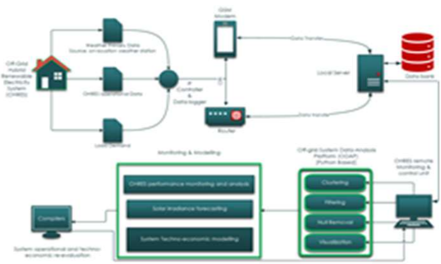

Figure 11 OSDAP updated functionality diagram

3. Hybrid Off-grid Techno-economic Model (HOTEM)

Third and last part of our publication is HOTEM. The Matlab based platform will be used to achieve the optimization goals by applying the Canonical Particle Swarm Optimization Algorithm (C-DEEPSO) which is built on swarm intelligent and differential evolutionary techniques that aim to finds the best composition of generation units and optimum energy storage operation mode [3]. C-DEEPSO will follow the techno-economic model towards the following optimization goals:

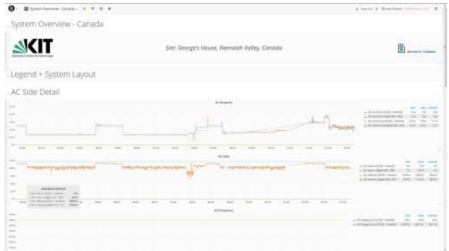

Figure 12 Remote data monitoring online platform example for Canada OHRES

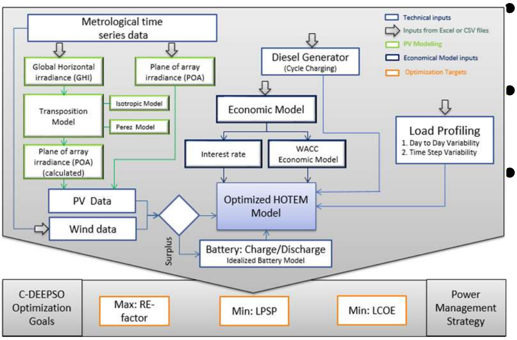

Figure 13 HOTEM model topology and structure

- Minimum Levelized Cost of Electricity (LCOE)
- Minimum Loss of Power Supply Probability (LPSP)
- A maximum Renewable Energy Factor (RE_Factor)

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Monitoring Results of Installed Solar Thermal Systems in the Southern African Region

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Keywords: Monitoring Results of Installed Solar Thermal Systems in Southern Africa

The SADC region is blessed with solar radiation between 1,800–2,400 kWh/m². Nevertheless only 0.3% of the worldwide solar thermal capacity is installed in the Sub Saharan African Countries. Therefor the main goal of the Project Southern African Solar Thermal Training and Demonstration Initiative “SOLTRAIN”, funded by the Austrian Development Agency (ADA) and the OPEC Fund for International Development (OFID), is to contribute to a changeover from a mainly fossil based energy supply to a sustainable energy system based on renewable energy. Within the SOLTRAIN project, companies, who took part in the several training courses, installed more than 300 Solar thermal systems in the past 9 years. Out of these systems different types were selected for monitoring in order to obtain a representative variance of the different system concepts and designs. The aim was to get information on the performance of the improved systems and to use this gained data for further evaluations. The recorded data of all systems were downloaded and analysed continuously and documented by the responsible project partners. With the help of the analysis of the data, the functionality and the possibilities for additional system improvements were figured out. The analyses and evaluation of the recorded data was done at least once a month. For all systems, a monthly monitoring report was prepared.

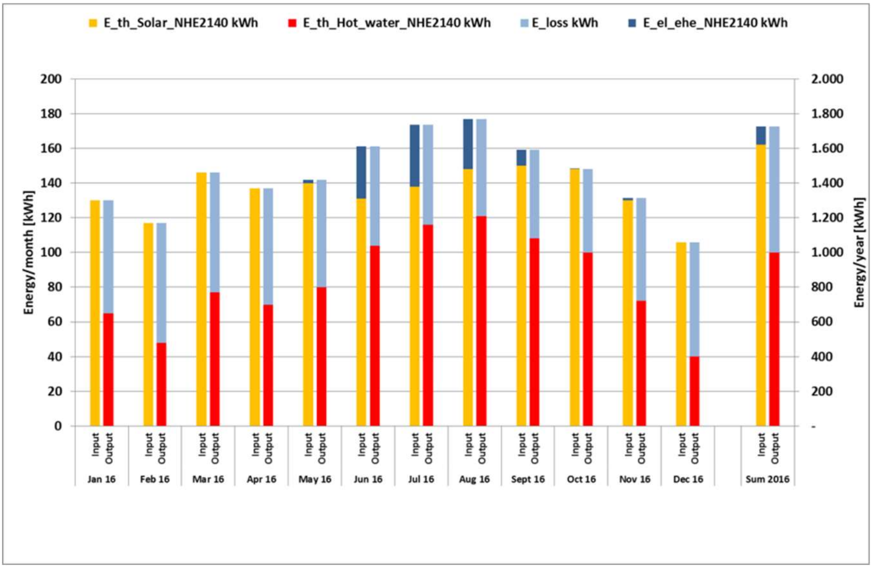

Figure 1: monthly energy balance of a monitored demonstration system

Based on the recorded solar thermal yields, the avoided CO2 emissions and electricity savings were calculated after the 12 months monitoring period. All this information has also been used in training courses offered during the project and gave a lot of practical information, key factors and knowledge about the performance of these systems.

The use of copmosite heating storage materials based on $Zn(NO_3)_2·6H_2O$ for space heating and domestic hot water supply in the Arctic region of the Russian Federation

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Keywords: zinc nitrate hydrates, PCM, TAM, supercooling, $Zn(NO_3)_2·6H_2O$, composites

Subtitle

The use of promising heating storage materials based on crystalline hydrates of zinc nitrate is an effective direction for the development of energy-intensive and resource-saving technologies, the development of which is provided for in the state program of the Russian Federation “Socio-economic development of the Arctic zone of the Russian Federation” No. 366. This is currently especially true in the northern regions, where the development of cheap and effective technologies that are available to the consumer is necessary. The use of energy storage systems will reduce the economic burden on the consumer by reducing heat losses arising from the system supply of thermal energy regardless of the required volumes of its use, as a result of which part of the thermal energy is lost instead of being accumulated and used later.

Salt hydrates are affordable and safe compounds for use as thermo-accumulating materials and are able to accumulate heat for a long time, as evidenced by high enthalpy values. In this case, crystalline hydrates are phase-change materials (PCM) [1,2], due to which they have a clear advantage over sensible heat TAMs, whose enthalpy is lower in the medium temperature range that interests us [3].

In our work, we propose several composite mixtures based on $Zn(NO_3)_2·6H_2O$ salt hydrate, the results of the study of which established their thermal stability in the medium temperature range, so that they can be used in a warm floor system for a long time [4,5]. Table 1 presents these mixtures in the temperature range from 30 to 40 °C. The measurements were carried out using the T-history method to ensure the reliability of the results under natural cooling conditions with a mass of a few grams of the sample. According to the results of the study, all mixtures had low supercooling.

Table 1. Characteristics of composites based $Zn(NO_3)_2 \cdot 6H_2O$

	T, °C	**supercooling**
Mixture 1	~29	2.7
Mixture 2	~36	3.81
Mixture 3	~36	4.44
Mixture 4	~29	3.63

Reducing supercooling is especially relevant for thermal energy storage systems, which can also be used as space heating and domestic hot water systems. PCM with different temperature ranges of melting / crystallization will allow more rational use of the available heat and control the processes of heating water for various needs. The given experimental characteristics show that the composites studied in the work can be used as PCM in the initial temperature range, which is especially important when rationalizing the heat energy consumption in secondary household problems.

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Heating storage materials based on $MgNO_3*6H_2O$

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Keywords: heating storage, phase change materials, solar thermal systems.

Subtitle

In this study, the task is to optimize the heating storage composit materials and methods for their preparation based on $MgNO_3*6H_2O$ with minimal supercooling and the absence of phase segregation. The materials have a phase transition in the temperature range from 45 to 75 °C, the heat of the phase transition from 50 to 158 kJ / g, ideal for combine with solar thermal systems.

The Russian government has approved a state program for the development of the Arctic until 2025. More than 2,7 billion euros will be allocated for its implementation. The problem of heat supply in the Arctic is difficult to access for traditional energy sources. The task of heating storage is very important. This is possible using to stable phase change heating storage materials.

Heat storage for space heating and domestic hot water requires efficient heating storage materials with an operating temperature range of 45 to 75 °C, without supercooling, with congruent melting and without phase segregation, stable, non-toxic, affordable and affordable. In this range, a number of crystalline hydrates of inorganic salts have phase transitions, which melt incongruently. The object of the present invention is to eliminate incongruent melting and to minimize phase segregation and supercooling of heating storage materials based on $MgNO_3$

One approach to get rid of incongruent melting is to create eutectic mixtures based on salt crystallohydrates. To minimize the exposure of the nucleating additives that serve as centers of crystallization. For eliminating phase segregation additives thickeners.

To confirm the properties of the synthesized materials by differential scanning calorimetry (DSC) investigated the melting temperature and heat, as well as the value of the temperature hysteresis. Conditions of experiment by DSC method: maximum heating temperature - 130 °C ; minimum cooling temperature - 0 °C; heating rate - 10 °C / min; atmosphere - N_2; cooling rate - 2 °C / min; gas flow rate - 40 ml / min.

The value of supercooling was determined in threefold repetition using the method of temperature history in the conditions of natural cooling of the sample about 10 g of the melted synthesized material.

	$T_{melt.}$, °C	ΔH.,Дж/г	$T_{hysteresis}$.°C	Supercooling
mixture 1	50.49	52.41	Absence	Absence
mixture 2	48.75	76.17	Absence	Absence
mixture 3	71.36	158.7	Absence	Absence
mixture 4	50.99	128.1	Absence	Absence

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Refrigeration appliances for mini grids: Options to keep energy consumption under control

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Keywords: mini grid, refrigeration, ice storage

Motivation

The use of refrigeration appliances as household refrigerators often dramatically increase the energy consumption of mini grid users due to the fact that AC available refrigerators are not designed for solar grids or even under consideration of energy efficiency. This leads to a general nonsatisfaction of mini grid users and operators. From the other side, the use of thermal storage is an attractive option to reduce energy consumption over night or days with low solar radiation. Several manufacturers have launched to the market innovations able to balance solar energy fluctuations in communication with the grid control units. However, the lower cooling capacity and higher price need to be taken in consideration.

Technical considerations

The energy consumption of refrigeration systems depends on thermal losses, which depend on the difference between ambient and cooling temperature, and refrigeration demand, which depend on the amount of products to be cooled down. Furthermore, vapor compression refrigeration systems decrease their coefficient of operation (COP defined as ratio between thermal energy produced to electricity consumed) by increasing ambient temperature. Therefore, refrigeration systems suitable for mini grids should consider the following aspects:

- Possibility to buffer thermal energy in e.g. ice storage designed for the expected daily cooling demand
- High insulation to assure an effective storage of thermal energy during solar radiation hours
- Consideration of heat transfer needs even during phases without energy availability
- Capability to measure grid frequency in order to operate the refrigeration system accordingly.

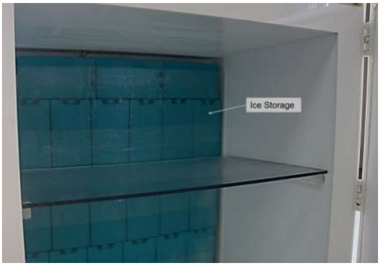

Figure 1: Refrigerator with integrated ice storage

Refrigeration systems designed for mini grids are able to store thermal energy at a maximum power rate during solar radiation hours and work efficiently or even reduce their electricity consumption to cero during periods of low Battery SOC. In order to assure a correct coordination with the grid control system, the operation strategy of the refrigeration systems need to be calibrated accordingly depending on SOC indicators such as frequency of the grid. The average amount of hours in which a refrigeration system can operate at maximal power determines the cooling energy that can be expected by users.

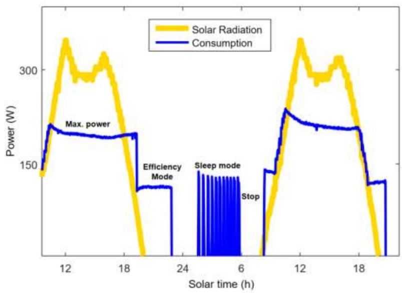

Figure 2: Operation strategy for solar refrigeration systems

Conclusions

While refrigeration systems able to deal with solar fluctuations are very attractive for mini grid operators, the right balance between energy consumption and cooling performance need to be designed carefully. A limited time to transform electricity in thermal energy means less total cooling capacity in comparison to systems that can work 24h per day. From the other side, Systems capable to store more thermal energy in less time require higher capacity compressors and are therefore more expensive. The extra investment cost of those innovative refrigeration systems, which causes less energy cost to operators, need to be compensated by a lower energy cost for final users while new tariff structures need to be developed accordingly.

Proposals to cooperation in overcoming poverty and lack of prospects in developing countries by Open Source Appropriate Technology (OSAT) and horticulture, and using revenues from the voluntary compensation of greenhouse gas emissions

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The presentation focusses on:

1) Development and dissemination of Open Source Appropriate Technology (OSAT) with worldwide participation of universities, foundations, innovation-institutes;

2) Overcoming the firewood crisis by improved stoves, thermos technology and solar cookers;

3) Opportunities of combining climate protection and poverty reduction with voluntary compensation of GHG emissions;

4) Benefits of the cooperation for the host countries;

5) Garden settlements with appropriate water technologies instead of slums, camps and reception centers;

6) Bio-carbon storage in the soil as carbon-sink in the gardens;

7) Ways out of the poverty trap by creating millions of jobs per year by Appropriate Technology and horticulture (Garden cities);

8) Promoting school solar cooker projects.

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[1] Publication "Opportunities and Recommendations for Appropriate Technologies in Developing Countries" http://solarcooking.org/seifert

Human capital development in higher education: a long-term, integrated approach for achieving SDG7

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Keywords: capacity building, energy access, skills and expertise, human capital

Human capital will be a vital part of achieving universal energy access. As a still nascent sector, training providers have not always yet fully responded to this the needs of the off-grid energy sectors. Furthermore, amidst the various donor support programmes directed at the off-grid energy sector, skills development is often the least common form of donor technical and financial assistance. The Transforming Energy Access (TEA) Programme sets out to transform and accelerate access to clean and affordable energy in Africa through supporting skills and enterprise development. This paper reports on experiences from the TEA Learning Partnership (TEA LP), a long-term higher education-energy sector collaboration that aims to deliver increased human capital for the energy access sector through the development of responsive, needs-based training and capacity building initiatives. It does this in collaboration with nine universities in eight African countries and the energy sector in these countries. The paper addresses three key areas of human capital development. Firstly, an assessment of the skills and capacity needs expressed by the off-grid energy sector. Secondly, the TEA LP approach to linking competency development in higher education to the needs of the off-grid energy sector. Thirdly, the importance of adopting a 'leave no one behind' strategy in human capital development to achieve better outcomes. These activities for human capacity building are expected to contribute to building a generation of skilled individuals that will develop the innovative solutions required to scale the sector.

Capacity building in developing regions

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Keywords: sustainable development, renewable energy, training, developing countries, market opening for the industry

Enhancing sustainable development in developing countries of this world (Abstract)

Technical empowerment is a topic at the root of sustainable and self-determined development. One way of enhancing the ability of people in developing regions to improve their living conditions is training.

Here the authors report on their experience with training courses in the area of renewable energy addressed at the international market and in particular to developing countries. Training, especially in combination with industrial partners and research institutes, offers a cutting edge view of developments and possibilities.

The inclusion of practical engineering topics is an essential part of appropriate training which aims at transferability and applications, particularly in technically less developed regions of this world. The German Solar Academy's (GSAN) intensive solar business training formats intend to contribute a big deal to improving the dissemination of PV technologies in addressed regions through educating and training people to become sales and installation partners for the international and local solar industry.

While politicians of western countries offer lip service to the use of renewable energies political action does not necessarily support such initiatives. In this report the capacity building work of GSAN and methodological issues of its activities are discussed, as well as obstacles identified.

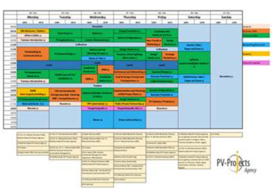
The German Solar Academy Network (GSAN) and the SRH Solar Winter and Summer Schools

Energy is a driver for economic growth. In sub-Saharan Africa, still close to 600 million people live in low-income regions with no access to electricity (IEA Flagship Report – November 2019). Photovoltaic solar “off-grid” systems could be able to boost sustainable economic growth. Besides the efficient allocation of financial means and a supportive political framework, the availability of system components of sufficient quality and access to experts that are able to sell and install renewable energy systems are crucial for a successful market penetration. Solar companies are the most dynamic factor with regard to further PV dissemination.

However, the solar industry struggles with finding "right" reliable and skilled partners in targeted markets. In cooperation with SRH Berlin, University of Applied Sciences, the PV-Projects Agency-Berlin, has introduced a training concept called "The international Solar Entrepreneur/Employee (TiSE/E)". This training programme addresses this bottleneck.

Short to long-term courses are offered in accordance with this concept and enable transfer of important solar business skills to potential future solar industrial partners at the Berlin location in Germany. Alternatively, training may also be offered at locations of international GSAN partner institutes.

A central part of the TiSE/E philosophy is to enable trainees to gather essential practical knowledge directly from qualified industry and academia players in the field and to find relevant and reputable contacts in order to be able to immediately start or improve work activities in the sector through a smart mixture of technology, business and networking sessions (business matchmaking).




Figures 1 to 3 (from left to right): timetable of 4th SRH Solar Winter School (first week) shows well the mixture of business and technical skills training as well as networking sessions, 4th Solar Summer Team-up! Flyer, 5th Solar Winter School marketing.

Since its formation in 2016 (official launch at 1st SRH Solar Winter School) the German Solar Academy Network (GSAN) organizes these schools. Apart from locations in Germany, the network realizes professional education (study programmes) and vocational training programmes in the Green Technology field in targeted partner countries worldwide in order to foster and support sustainable energy use as well as waste and water management. It builds competence centers (establishes partnerships with existing vocational training institutes) and relations to central authorities in attractive markets. GSAN ensures quality management, and it introduces and maintains common standards in its educational co-operations. It provides key educational concepts (curricula, training skills and methods) and material that is of a high-level (up-to-date scripts and lecture notes). Furthermore, it serves as a certification and branding agent.

Achievements

- 5 *SRH Solar Winter Schools* in Berlin (every February, since 2016) - 78 graduates

- 5 *SRH Solar Summer Team-up!* in Berlin and diverse German locations (every Summer in the context of either *Intersolar/The Smarter E* or *Off-Grid Experts Workshop*, since 2016) - 65 graduates

- 1 *SRH Intersolar2019 Business School* (SIBS2019) in Berlin and Munich (May 2019) - 3 graduates

- 1 *Short Solar Training* of Northern-Iraqi delegation in Berlin in Berlin (September 2018) - 16 graduates

- 1 *Virtual Training Course for Future Solar PV Capacity Building Partners* (Train-the-Trainer for GIZ Iraq, November 2020 - January 2021) - 21 graduates

- 1 *Accreditation Wind Energy Workshop* for new Wind Energy Trainer of the *Green Energy Academy* (GEA) in Berlin (July 2018) - 8 graduates

- 2 *GSAN International Wind Industry Training* (GSAN-iWIT2019 and 2020) in Berlin (December 2019 and November/December 2020) – 16 graduates

- Establishment of training programmes at Vocational Training Centers in Accra and Tema (Ghana) with *Builders of Tomorrow Association* (BOTA), since 2016 - 40 graduates

- Establishment of training programmes at Vocational Training Center in Yaoundé (Cameroon) with the *German Solar Academy Cameroon* (GSAC), since 2017 - exceeding 150 graduates

- Establishment of training programmes at Vocational Training Center in Freetwown (Sierra Leone) with the *FLS Academy*, since 2019 - 13 graduates

- Establishment of training programmes in Egypt and Saudi Arabia through the *Green Energy Academy* ("SDSB training"), since 2018 - exceeding 220 graduates

- 10-day Private Sector Development (PSD) solar technology training in Erbil, Kurdistan region of Iraq for *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) (November 2019) - 24 graduates

- Great reception from the solar industry and training support in Berlin and at company-sites by industry partners: Phaesun, Solara, Studer, SMA, SMA Sunbelt, Fronius, Synlift Systems, Phocos, Energiekonzepte Schiffer, Schnelle Energietechnik, Raach Solar, Oneshore, SunEnergy, Hoppecke, Ecoligo, Solarworld, Schneider Electrics, Steca, 4Newenergy, BAE Batterien, Little Sun, Redavia, OC3 AG, Astronergy, Infinite Fingers, Morningstar, Solar Kiosk, WestfalenWind, MCD, PP Power.com, Abhijay Energy, Synergy, Solarwaterworld, GreenRock Energy, Skytron, Asantys Systems, Solar Cooling Engineering, Sunfarming, Photovoltaikbüro Ternus&Diehl, Phoenix Contact.

- Great training and networking support by NGO's, GO's and consultants Enerpol, PV-Projects Agency, RLI Reiner Lemoine Institut, Wollny Consulting, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Deutsche Energie-Agentur (dena), Landesstelle für gewerbliche Berufsförderung in Entwicklungsländern, d-collective/d-network, Institute of Applied Resource Strategies, Green Energy Academy, Afrolynk, Dynamo, The Smarter E, Embassy of the Republic of Sierra Leone, Messe Augsburg, INTEGRATION environment & energy.

- Great wind industry support: MHI Vestas Offshore Wind, Bundesverband Kleinwindanlagen, ProfEC Ventus, XVentum, ERNI windradkollektiv, enbreeze.

- Great support through SRH professors and lecturers (in average 7 per school)

- Acknowledgement through Renewable Energies Export Initiative Secretary at the German Ministry of Economics (BMWi)

- Outreach to new markets through SRH Solar Winter or Solar Summer School participants in countries like Sierra Leone, Cameroon, Lithuania, Mexico, Colombia, Saudi Arabia, Egypt, South Africa, France, Ghana, Tanzania, Uganda, Eritrea, Bangladesh, South Korea, Thailand, Australia, Canada, Nepal, Djibouti, Sudan, India, Somalia, Iraq, Nigeria, Brazil, Portugal, Indonesia, Tunesia and Honduras

- Establishment of (a couple of close) business partnerships between participating industry partners and trainees (to be further evaluated)

Challenges

Despite great successes in conducting the schools with exciting outcomes, great satisfaction and gratifying feedback of trainees, challenges remain regarding the maintenance of successful collaborations with existing industry partners and a continuing successful acquisition of new solar companies that present state-of-the art technologies and services and that are looking forward to participating in training events.

However, due to present German government policy, allowing participants to actually travel to Germany (e.g. due to visa issues) remains by far the biggest obstacle to participation in scheduled events.

With increased training activity handling the organization and a worldwide network, including communication with GSAN partners, as well as the creation of new training formats also beyond existing markets, will only be mastered through increased manpower.

Conclusions and Outlook

4 years after the launch of the GSAN more than 10 intensive solar business training events have been carried out in Berlin including company, project-sites and trade-show visits in Germany. Almost 200 persons have been trained; 78 candidates have been SRH-certified and now carry the title "SRH-certified Solar Employee" or "SRH-certified Solar Entrepreneur"; 5 people have become accredited GSAN training partners.

GSAN's international network has successfully grown, now including 6 new training centers in Cameroon, Ghana, Sierra Leone, Egypt and Saudi Arabia, with partners collaborating well and efficiently. An additional 400+ people have successfully completed programmes in these partner institutions and 24 in a customized training in Iraq.

The German training events work very successfully with a high standard of quality level and training programmes receive external recognition. However, further efforts will be required to ensure that a sufficient number of trainees actually attends these sessions each year. Resistance from German embassies regarding visa issues needs to be overcome. Ministries and other influencers will be contacted, and partnerships will need to be established in order to support competence dissemination in the field of renewable energies.

Future events include the third *GSAN International Wind Industry Training* (GSAN-iWIT2021) event which will be held in Berlin in December 2021.

In September/October 2021 the *6th SRH Solar Summer Team-up!* will take place in the context of the Munich Intersolar/The Smarter E.

In March 2022, the *6th Solar Winter School at SRH* will be held in Berlin.

The *GSAN PV-Business online Training (SRH-certified and on-demand)* will be developed further and introduced to the public. A 3-day preparatory solar training event at partner institutions (e.g. Ghana) will be implemented in order to circumvent visa restrictions.

Customized solar trainings (incl. Train-the-Trainer component) will be offered to international governmental and non-governmental organizations. Furthermore, a roll-out of extensive training measures is planned in Pakistan.



Figures 4 to 7 (from left to right): Prof. Dr. Michael Hartmann teaching at the 2nd SRH Solar Winter School, trainees installing a 1kWp PV system on the terrace of the SRH building, 4th Solar Summer Team-up! with Prof. Dr. Klaus-Ulrich Neumann, Mini-Grid session with Prof. Goran Rafaljovski

Further development and improvements of courses are intended, guided by extensive evaluations through surveys of trainees and industry. GSAN will also continue to develop training programmes at its new partners' locations in Colombia, Nigeria, Northern-Iraq, Zimbabwe and India.

Innovation diplomacy as a driver of the energy transition

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Keywords: innovation diplomacy, energy transition

Introduction

The energy sector is undergoing a process of strong transformation. Given their relevance to greenhouse gas emissions, energy systems are the center of global warming mitigation actions. This transformation, called the energy transition, is led by developed countries and results from policies for the energy sector, with a particular focus on the diffusion of renewable sources for electricity generation. The ability to generate and disseminate innovations can be seen as a diplomatically strategic element to accelerate the transition to a sustainable energy system.

Technology in the core of the long-term transition

Among the common factors associated with a transition, the pursuit of greater efficiency, the modernization of infrastructure and the addition of production capacity from renewable sources are the main axes of transformation. However, it is common to observe several electric utilities that are economically weak. Diplomatic measures focusing on innovation would therefore be essential to improve the visibility and viability of low carbon technologies and processes in investment planning of those utilities. Such measures would include raising awareness and encouraging the adoption of technologies and practices to expand the use of renewable energy.

Conjoint innovation projects

In the area of science, technology and innovation, it is possible to structure cooperation by various means, whether informal or formal. By creating a research infrastructure platform, a memorandum of understanding on research and development cooperation is established between countries, setting priorities in energy transition, such as innovation in renewable energy and energy efficiency; innovation needed in the end-use sectors; zero-energy buildings; and new materials for advanced battery storage. From this, technical and investment partnerships between state-owned companies are developed.

Setting up ambitious innovation centers

The creation of ambitious innovation centers should aim at enhancing the national R&D production mode, being able to act simultaneously on four critical aspects that constitute the basis of a knowledge and innovation production system: infrastructure; fomentation; qualified human resources; and innovation. It is the articulation of these dimensions that allows us to maximize the investments made in laboratories and equipment, design and implement new support modalities, execute brain gain programs, incorporate new generations of researchers and encourage the search for patents.

Conclusion

In conclusion, to achieve the energy transition, the following are essential: deepening the internationalization of scientific and technological production; stimulating networking and cooperation based on multi-user and transdisciplinary laboratories, articulated by solid and world-class core competencies; and the concentration of material and human efforts on key areas to bridge the gap between knowledge generation and world technology.

SESSION 3

LESSONS LEARNED: FAILURE AND SUCCESS FACTORS

THURSDAY, September 16

African villages electrification

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Keywords: Electrification, Hybrid, Energy Storage, PV

Electrification: what are the options?
The electrification of African countries is becoming increasingly vital, not only to serve basic human needs, but also to access commercial and developmental opportunities.

The first and seemingly simplest solution is to install additional diesel generators to provide electricity over a longer period of time. Despite appearing straightforward, this solution has several drawbacks; in some remote areas, access can be a significant challenge not only in terms of installation but also when it comes to refueling. Additional generators come at a price, with the rising cost of fuel being a serious drawback but also in terms of the negative environmental impact. The associated increase in CO2 emissions is in direct conflict with wider sustainability objectives making it both impractical and unattractive to deploy additional generators.

A second solution is the installation of large scale photovoltaic plants of several tens of MW, used as standard thermal power plants to guarantee a stable power supply. Generally, these are connected to the grid and their size is sufficient to cover the annual needs of the population, enabling access to education and medical care, for example. On the down side, however, it doesn't work for isolated sites that are not connected to the grid.

For these off-grid isolated sites, creating new infrastructure for connection to the grid is not a workable solution – as well as being cost-prohibitive, the complexities in terms of access are difficult to address successfully. In the case of industries, hospitals, entire villages or even islands, the most pragmatic solution would be the installation of solar panels in conjunction with a battery energy storage system; this was exactly what was done by us in the project we will present you.

18 months to electrify isolated African Villages
A project has been running in Senegal since 2017 to electrify very remote areas.

The tens of MWp of PV installed for this project aim to meet the annual needs of 140,000 people - whilst also reducing atmospheric CO2 emissions amounting to 18,919 tons per year. In addition to solar panels, the plants also include generator sets and batteries.

To support this development, Socomec supplied and installed 4 energy storage systems – from 132 kW / 183 kWh to 396 kW / 731 kWh - composed of lithium-ion batteries, with Socomec DC and AC distribution cabinets and controllers. Delivered in maritime containers, the installation supplies 4 islands; with a combined total of 1 MWp of photovoltaic panels, they reduce the use of the Gensets, diesel consumption and harmful CO2 emissions - and provide the islands and other remote locations with unprecedented reliability and control.


socomec

Success of self-sustainable off-grid rural electrification projects in India

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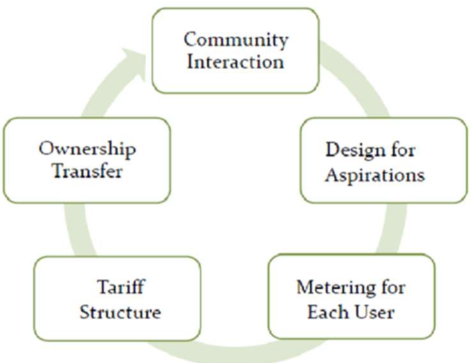
Keywords: Micro-grid, Self-sustainablity, Circle of success

Gram Oorja fulfils the electricity, domestic and irrigation water and cooking fuel needs of remote communities. With over 250 community scale renewable energy projects including 67 micro-grids, Gram Oorja's work has impacted over 60,000 people.

To make projects successful and sustainable, the appropriate interventions required in remote communities have to be well thought out taking into consideration various issues relating to governance, social structures, topography and politics. It is important to understand that the micro-grid is not about just delivering hardware to the village, or giving connections to each household. It is a system that needs to be energized by involving the local population, discovering the principles of management of the system, hand-holding the process of inaugurating the grid and finally, ensuring the long term support - technical and social - to the final beneficiaries. Most of Gram Oorja's work in micro-grids has been in remote villages and each one of these micro-grids have seen gradual increase in usage of power and a total ownership of the village community in maintaining these grids.



According to Gram Oorja, in the current scenario, it is enough if someone wanting to make an impact on village life using energy, can set up a micro-grid which is sustainable with a one-time investment. In other words, the beneficiaries bear the maintenance cost over the project life-cycle, which in cases of solar based micro-grids, could mean around 25 years.

This enables one whole generation of the village community to enjoy the fruits of a one-time investment. Over the project life cycle, this could mean that the village bears around 60% of the overall cost. Gram Oorja believes that sustainability of such projects could be largely ensured by following what is known as the “Circle of Success”.

Community interaction is critical since both the producer and the consumers are based in the community. It also ensures that people take ownership of the project, and is also critical for tariff discovery. Metering ensures accountability and discipline of usage. Ownership transfer at some stage also ensures that the village community looks upon the asset as a long term addition to their lives. Load feasibility study is crucial in designing a system, which will not only meet the energy requirements of the users but will also cater to their growing aspirational needs.

This paper will examine the successful projects and look at the various technological and social factors that have contributed to the success. In rare cases, the projects have faced sustainability challenges and this paper will examine the risk factors and propose risk mitigation strategies.

Assessment of electrification options for off-grid areas in Cambodia

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Keywords: Energy Planning, Least-Cost Electrification, Reference Electrification Model (REM),

Assessment of electrification options for off-grid areas in Cambodia

The objective of this project is to assess the electrification options for providing grid or near grid quality electricity to population clusters not covered by the existing and planned electricity transmission and distribution grid. In particular, the analysis will consider the investment and operational cost viability of key renewable energy alternatives relative to other options for electrification to reach the Royal Government of Cambodia's ambitious electrification targets. The consultancy will support the Technical Working Group (TWG), which has been created to prepare the Draft Renewable Energy Master Plan 2019-2030, the Ministry of Mines and Energy (MME), the *Electricite du Cambodge* (EDC) and Electricity Authority of Cambodia (EAC). Specifically the assignment will assist the TWG and MME with the update of the National Power Development Plan (NPDP) 2019-2030 and provide input for renewable energy resources to be included in the plan.

The analysis will be conducted making use of the Reference Electrification Model (REM). The REM is a computer-based optimization tool Developed by MIT/Comillas-IIT Universal Energy Access Lab that performs automatic electrification planning and is able to identify lowest cost system designs to most effectively provide desired levels of electricity access to populations of any given size. In doing so, the model determines the most suitable modes of electrification for each individual consumer. Concretely, this represents specifying whether customers should be electrified via grid extension, off-grid mini-grids, or stand-alone systems. For each system, the model supplies detailed technical designs at the individual customer-level.

As part of the assessment, the team will review the existing institutional and regulatory framework and previous experiences for off-grid electrification development and provide recommendations based on international best practices for the successful implementation of the proposed technical solution. The Consultant will support the TWG and MME on how to update the NPDP 2019-2030 based on the technical results and how to consider them for the RE Plan.

SESSION 4

KNOWLEDGE TRANSFER, OPTIMISATION AND REGULATORY FRAMEWORK

THURSDAY, September 16

Global online knowledge management on energy access via energypedia

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Keywords: Knowledge Management; open source; learning; lessons learnt

Knowledge Management

Often first-hand knowledge on modern and sustainable energy technologies only exists locally or in fragments and is thus difficult for individuals to access. A variety of case studies, success stories and evaluations among the different technologies and approaches exists. However, every organisation and institution has their own data storage system and their own methods of sharing these type of information. As a result, a lot of information about experiences is lost. There is a need for facilitating and expanding the diffusion of these technologies in developing countries through practical knowledge sharing. This presentation will take a look at the solution to make knowledge available via energypedia and how all participants of the conference can contribute and share their valuable insights for all on energypedia.

www.energypedia.info

Energypedia hosts www.energypedia.info, a wiki-platform offering free access to expert information on renewable energy, energy efficiency and energy access in developing countries. Every user can create content and make it directly accessible online. In this way, energypedia promotes the necessary international knowledge exchange between a growing community of over 9,000 experts and practitioners in civil society, academia, the public as well as the private sector. Thus, energypedia does not only facilitate typical knowledge exchange between industrial and developing countries, but also promotes the direct exchange of experience among people in developing countries. Each month the platform has over 60,000 unique visitors.

Energypedia has developed **15 knowledge portals, 5 energy databases, webinar series and other knowledge products**. Over the past years, we also collaborated with many such as GIZ, ESMAP, Practical Action, UN Energy Access Practitioner Network, ACCESS Coalition and Energy for all Partnership.

One of the main strengths of energypedia is its **user-driven focus** i.e. all the content on energypedia has been generated by the users and is free to read, edit and share by all other users. The information on energypedia (such as lessons learnt, case studies, country energy situations, technology specific handbooks, experiences of impacts, and many more) prevent energy access practitioners from reinventing the wheel, saving time and effort and ultimately enable them to increase energy access for all. Another innovative strength of energypedia are the innovative tools that allow energy practitioners to showcase their work of and to collaborate on innovative ideas with others.

Join the global, collaborative knowledge exchange platform and contribute with articles to the following portals: Energy Access Portal | Mini-grid Portal | Solar Portal | Figures on Access to Energy | Renewable Energy and Energy Efficiency Project Resource Center | Browse all portals

Energypedia furthermore entails an event calendar, a job portal, an opportunity database and a publication database

Promoting solar cooling through technical training courses

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Introduction

Rural electrification through solar home systems (SHS) and mini-grids have given access to electricity to thousands of households in recent years. Together with lights, mobile phone chargers, TV and fans, the use of refrigerators is one of the most popular appliances. In addition, a productive use of energy for ice-makers or cold rooms represent a promising business opportunity for mini grid users and enterprises.

Challenges

Conventional refrigeration systems are often not designed for its use in SHS or mini-grids causing to users and operators unexpected high energy consumption. From the other side, solar experts usually cannot yet estimate the effect of ambient temperature and operational profile into the daily consumption or evaluate the potential of thermal storage to reduce it. In addition, manufactures willing to launch innovative solar cooling systems face the challenge to adapt the systems to local needs while been able to keep cost low.

Approach

An innovative technical training course has been designed to link knowledge of different disciplines such as product development, local production, maintenance and assessment of business models. The approach offers technicians, engineers and decision makers the possibility to learn basis on refrigeration technologies and design methods. Small-scale cooling units are used to create, assemble and test hands-on cooling systems for several agricultural value chains. Once the technology has been understood, the design of the solar system based on excel calculation sheets plays an important role to asset economic indicators. Highlighted is the potential of local produced innovations to generate income within the agricultural sector. This represent a business advantage for entrepreneurs which can import key components while adapt rapidly to the demand and size of their customers.

Experience

The training courses are based on four years pilot experience and assessments on willingness to pay of cooling systems in rural areas. In 2019, eight different example systems have been used to train 150 participants of 15 countries in Kenya, Mali and Germany. Constructions manuals have been developed to help local experts to estimate the cost of local produced components while most promising business cases are commonly assessed for different value chains. Following similar construction steps and key components, technological solutions have been developed for milk cooling in cans or tanks, cold rooms of different sizes, water chillers and ice-makers. With the support of SWOT analysis further steps are determined for a sustainable cooperation between African and European institutions. Special attention is given to understand the local context and avoid donations which often negatively influence the emerging local market on cooling technologies.

Conclusion

A sustainable introduction of solar cooling technologies still lacks on capacity building measures to support not only distribution and maintenance but to open up business opportunities through cooling solutions adapted and repaired locally. Trainings can only have a positive impact if accompanied by practical knowledge able to give local skilled staff a sustainable perspective for employment.

Battery training for PV-Hybrid and mini-grid
A real tool to optimize the projects

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The aim of the article is to report experiment of training focussed on batteries toward companies involved in design, installation and maintenance together in Western Africa together with their customers

This original way of doing afford many advantages which are understanding of the specific technical words used for battery systems, the key criteria to address the technical choices, the maintenance issued of respective choices, a view of how to integrate the possibility of electrical power storage extension to answer to an increasing energy demand in future.

Battery physical understanding drive to optimized technical choice: The battery technologies need to be highlighted to avoid misunderstanding and help to focus on right parameters to draw projects technical specifications linked to application purpose in the aim to optimize TCO regarding original CAPEX.

Battery systems operation mode knowledge is a must: Battery box cannot work without adapted connexion to charger, monitoring systems, supervision network and load management. This point is clearly, in a world where the technologies linked energy storage are going faster, a necessity. This knowledge allows to get a full energy storage system in line with the way of operation, which is originally thought, including way of maintenance, way of information transmission and way of information treatment which are becoming an important factor in term of maintenance cost and at least TCO.

State of the art of various battery technologies ranges and systems appreciation is becoming an appreciable tool to optimize the choice. The possibilities are multiple today, the CAPEX cost cannot be the unique criteria and TCO appreciation need to have a good technical picture of what is today available in a world where the variants of different technologies are numerous and improving very fast.

Training session should meet higher level: today many training sessions around battery systems are looking at how to torque a screw or how to fill water in a jar. This is not very adapted to help decider, operator or integrator to draw adapted technical specifications in line with the expected results. According there is a very little university with adapted course about batteries system throughout the world, except some dedicated universities, an enlargement of energy storage systems should offer the possibility to develop energy storage systems for off-grid, hybrid or grid-connected network at quite lower TCO cost.

Potential Energy Savings in Interconnected Domestic Solar Systems

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Keywords: peer-to-peer, P2P, energy trading, solar energy, home solar systems.

Solar energy has been one of the most widely used renewable resources in microgrids and nanogrids around the globe. However, typically the residential load profiles have their highest peak when solar energy production is lower or equal to zero (between 6 pm to 9 pm). Also, when there is a peak in solar energy production, generally it does not coincide with the period of great demand in residential units, often requiring generation to be curtailed. This work suggests a better use of wasted energy by connecting generating and consuming units together.

In this study, we analyze the potential of energy savings possibly when interconnecting "solar home systems" (SHS), small single-household PV-battery systems. The study performs a boundary case (limiting) analysis of the relationship between the energy savings potential and the load curve variability. For this study, artificial load profiles were created, based on residential load profiles in rural villages, which have few electrical appliances available, like light fixtures, cell phone chargers, radio, and television. A simulation was developed in MATLAB/Simulink, with 8 generating and consumer units interconnected, with each unit having its own storage system. It was used real solar irradiation of Mayange, a sector in Rwanda, provided by the Rwandan Meteorological Agency.

The simulations varied load profiles between real world scenarios and limiting conditions which have a low probability of occurring in a real environment. This analysis illuminates the maximum energy sharing that could result from interconnecting these small systems. Results show that the maximum diversity in load profile peaks produces the greatest outage improvement 14.3% [0% to 33.3%], which decreases with decreasing load diversity to a low of 15.4% [14.9% to 16.0%]. The larger of these two numbers likely reflects the best-case outage reduction achievable by interconnecting SHS. Similarly, the outage hours improvement ranges from 25.6% [16.5% to 41.7%] for the most diverse case to 59.6% [59.1% to 59.9%] for the least diverse test case.

Due to the small power savings, relative to the cost of interconnection power electronics, wires, insulators and poles, the economics of interconnected SHS are uncertain, and should be more precisely modelled to guide appropriate investment.

Optimal Integration of Photovoltaics in Micro-Grids that are dominated by Diesel Power Plants

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Keywords:

In this study the effects of PV integration into diesel driven micro-grids was investigated. The focus was set to the fuel saving potential due to the PV integration and the resulting economics for the system.

First a summary of the most relevant technical aspects that need to be considered for the integration of PV in a diesel driven micro-grid are presented.

On this basis the different types of systems that are of interest for the integration of PV are listed and from this analysis three case studies with quite different electric demand profiles were identified for which a detailed simulation was performed. The focus was on the effects of varying PV penetrations and the corresponding fuel saving potential and thus the economics of the system. The systems under investigation were typical diesel driven micro grid use cases, a Hospital complex in Haiti, a rural village in Nepal and a mine in South-Africa. To get comparable results for all systems the same specific component costs were assumed.

The simulations showed a reduction of fuel consumption and the levelized costs of electricity (LCOE) for all systems and all PV penetration levels based on peak power except for very high PV penetrations (> 150%) for the case of the rural village in Nepal. The benefits were particularly high for the Hospital case in Haiti where the demand fitted very well the PV production curve and the mine case in South-African where the load was extremely constant on a high level.

By adding a battery to a PV diesel system, the LCOE remains the same or even decreases slightly in the case of the rural village were the demand does not fit well with the PV production curve, but allows for higher PV penetration and a higher overall share of renewable energy. As a rule of thumb, a battery capacity of 30% of the maximum load value could be assumed to be reasonable, depending on the battery system cost that was estimated with a conservative value of 800 Euro/ kWh.

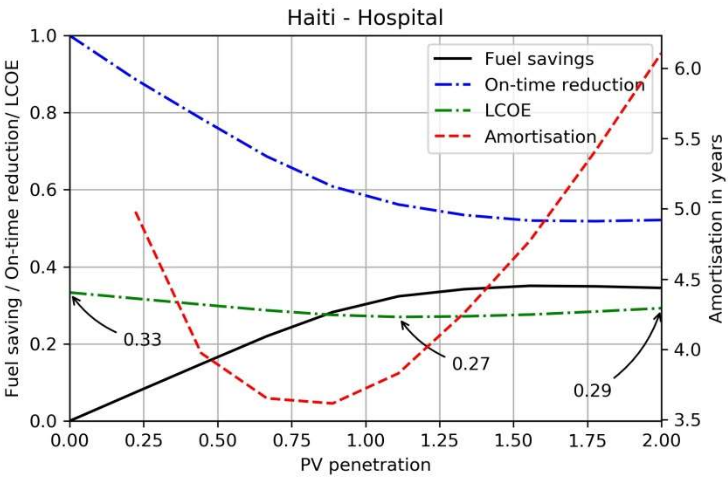

Figure 1: Fuel saving potential, on-time reduction and amortization time as a function of the PV penetration factor for the Haiti case-study with a battery storage of 540 kWh corresponding to 30% of the maximal load

For use-cases where the load is not well fitting the PV production, the integration of a storage system can be of even higher interest. Particularly if the battery prices are further reducing and the diesel prices are remaining on high levels.

interactive multicriteria optimizer for designing microgrid wind-PV electrification systems considering managements constraints

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Keywords: rural electrification, microgrid optimizer, electrification system design, multicriteria decision process, management constraints

Stand-alone electrification systems based on a combination of solar and wind energy are a suitable option to electrify rural communities, since they complement to each other and ease continuity of supply. In addition, the combination of microgrids, for concentrated points, and individual supplies, for scattered houses, helps balancing microgrid benefits (flexibility in consumption, economies of scale, etc.) and cost increases due to grid extension. There are tools to assist the design of these systems, but they mostly focus on cost optimization and technical aspects. However, management issues (i.e. users' organization to operate and maintain equipment) have been proven essential to ensure the long-term sustainability of projects. Therefore, the multicriteria nature of the project demands a consequent approach in order to select a balanced electrification design considering economic, technical and social criteria.

In this context, this work develops the tool Microgrid Optimizer (MO) to design electrification systems (Figure 1) including multicriteria decision-making to contrast the economic and technical viability of the project with management and social considerations. In particular, constraints are introduced to adjust the number and size of microgrids, to guarantee equity between users and to maximize the social benefits for communities. The solutions obtained define the location and size of the equipment to be installed for electricity generation, storage and distribution.

The design process is structured in two decision levels to progressively define the detail of the electrification system. At the first level, several electrification alternatives are generated minimizing the cost for a set of different demand scenarios. These alternatives are ranked according to a flexible multicriteria decision process which allows modifying the default weights to give more importance to some particular criteria. Once the weights of the first level criteria are adjusted, some solutions can be selected for further analysis in the second level. The alternatives generated for this second level consider constraints regarding the size and number of microgrids to ease the systems management. In the second level, criteria weights can also be adjusted, so the final solution can be adapted to the needs of both the community and promoters.

MO is supported on a free, easy-to-use web page which includes instructions about how to use the tool, a detailed explanation of the decision process and references to published articles in major reviews about energy topics. The user of MO is guided throughout the design process in an interactive environment, which covers from a template to introduce initial data in Excel form to reports of the design configuration. Moreover, the whole design process allows testing many design options in only a few minutes of computing time.

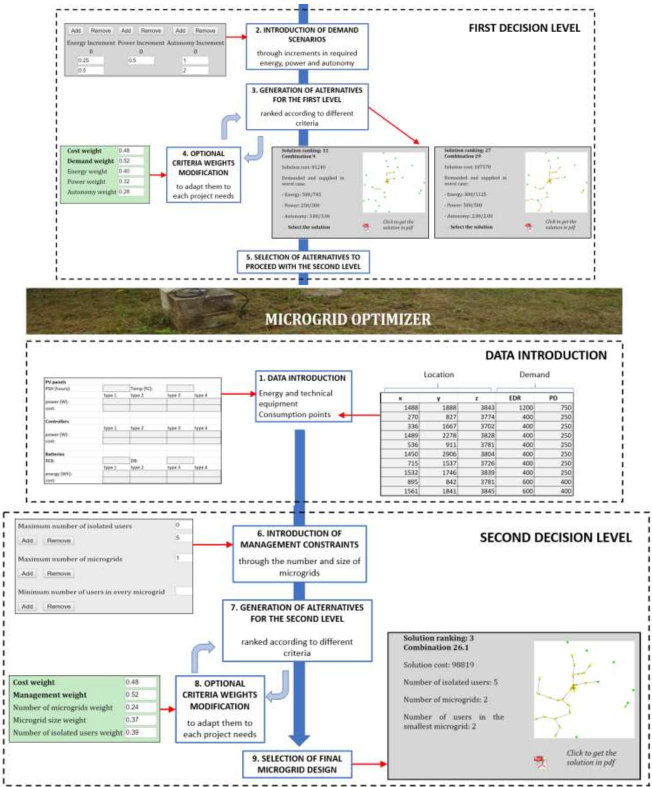

Figure 1. MO decision process illustrated by a flow diagram, complemented with captures taken from an example project

Quality Assurance Framework for Component Based Solar Home Systems in Uganda

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Keywords: Solar Home Systems

The Energy for Rural Transformation (ERT) is a Government of Uganda – World Bank supported programme that started in 2001 to promote the transformation of rural areas in Uganda. The third phase of the ERT programme focuses on increasing access to electricity in rural areas of Uganda through on-grid and off-grid technologies.

Global Sustainable Energy Solutions (GSES) has been contracted by the Ugandan Rural Electrification Agency (REA) to develop the Quality Assurance Framework for the component based solar home systems.

Under ERT-3, the Uganda Energy Credit Capitalisation Company (UECCC) is managing a line of credit and guarantee facility to promote the deployment of quality-verified off-grid solar systems. The Quality Assurance Frameworks will support this objective.

GSES has five major deliverables within the project:

- Developing the interim quality assurance framework to support the existing UECCC managed loan facility.
- Undertake the implementation of this interim framework by: assessing the individual system components and system designs; evaluating installers and installed systems of 10 companies that are applying to obtain finance through the UECCC.
- Develop the interim framework into a sustainable long term quality assurance framework through identifying the structure of a committee/organisation that would continue to oversee (or manage) the framework on an ongoing basis.
- Build the capacity of Uganda National Bureau of Standards (UNBS) or a designated third-party to assess the quality of components, design of systems, warranty terms and quality of installations.
- Evaluate the current capability and identify gaps of the UNBS laboratories to support testing of component-based solar products.

Two guidelines have been developed for the Interim Quality Assurance Framework :

- Solar Home Systems - Maximum Array 1 KWp - System Design Guidelines
- Solar Home Systems - Maximum Array 1 KWp - System Installation Guidelines

A training course has been conducted on the two guidelines and a multiple choice examination was developed. Companies applying to obtain loans through the loan facility must have installers that have passed the examination and all systems shall be installed in accordance with the guidelines. Inspection of systems will be undertaken in 2020.

For the long term Quality Assurance Framework :

- Two guidelines are being developed
  - Off-Grid PV Systems - Array greater than 1 KW_p - System Design Guidelines
  - Off-Grid PV Systems - Array greater than 1 KW_p - System Installation Guidelines
- GSES will work with UNBS and stakeholders to turn the guidelines into local standards (Codes of Practice
- GSES will review the existing "Assessment and Training Package for Solar Photovoltaic Electrician" that was developed by the Directorate of Industrial Training.

This paper will provide an overview of the activities undertaken and the current status of the project.

Adoption of Solar Water Pumps in Tanzania: The Farmers' Perspectives

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Keywords: Solar water pumps, solar irrigation, smallholder farmers, horticulture, theory of change, participatory rural appraisal

In Tanzania, solar water pumps experience sparse uptake by smallholder horticulture farmers. Thus, there is a need to surface information about the conditions on-site and provide an improved understanding of early-state challenges as well as of the farmers' situations and expectations. Moreover, expected benefits require validation. In order to assess the potential impact of solar water pumps, a logical model is developed according to the theory of change leading to a results staircase, which links the desired impact with required interventions. Field surveys based on participatory rural appraisal, during which 12 farmers are repeatedly visited during 13 weeks, deliver in-depth information on farmer level. Thus, farmer profiles are created encompassing among others farming details and water supply information. It is found that what farmers value most in a water supply system is reliability, followed by low operational costs and simple handling – all characteristics of solar water pumps and drawbacks of fuel pumps. However, most farmers require financial service, which indicates the initial investment barrier. Logistic troubles due to Tanzania's vast area result in unsatisfactory quality of service and increased costs constituting additional challenges. Moreover, assessing the farmers' needs and providing a properly designed system proves to be particularly difficult. Insufficient quality of water sources and deficient briefing of customers complete the early-state barriers encountered. The severity of the barriers is highlighted by the limited progress experienced by the farmers on the results staircase. Nevertheless, the logical model is partly verified, indicating solar water pumps' aptitude to enable rural prosperity.

Isla Huapi: setting up a sustainable business model for stand-alone PV

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Keywords: sustainability scheme, rural community, stand-alone photovoltaics

In 2019, 0.4% of households in Chile do not have access to electricity. This small percentage equals 25,000 houses and among of them, 7,000 would only have electricity through individual stand-alone PV systems. The Ministry of Energy is working on the design and implementation of sustainable business models to manage the maintenance and repair needs of those systems.

Isla Huapi is an island in the south of Chile where issues related to land ownership prevent us to develop a microgrid. It was decided that each of the 150 households would receive a stand-alone PV system. Considering the initial investment of USD 16,000 per system, it was a major need to set up a sustainable business model that would also become an example for other projects.

Design of the business model

Isla Huapi's inhabitants demanded to be in charge of their project. Thus, the Ministry of Energy proposes a mixed model which brings dynamism and flexibility for day-to-day tasks.

As shown in Fig. 1, the individual users are organized in a committee. This committee takes care of the technical maintenance and administration. This is allowed by a lease contract signed with the Municipality while this institution remains the owner of all the equipment. Each user, as part of the committee has the right to use a PV system following the terms signed with the committee on the on the agreement of duties and rights, which includes the obligation to pay a monthly fee. The Ministry of Energy plays a role as advisor, supporting the work of all stakeholders both in technical and management duties.

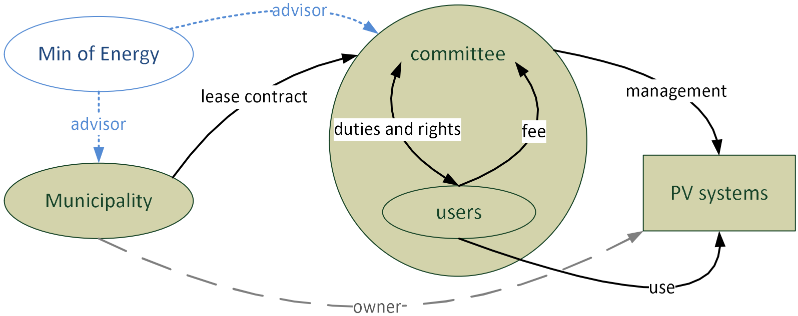

Fig. 1. Conceptual design of the business model

By leaving the equipment as Public property, the State would be able to invest again when the systems need the replacement of critical equipment. Otherwise, each user should deal with this big investment with its own financial resources which are out of their income level. The monthly fee is intended to finance the yearly maintenance of the systems. The committee, as a private and independent organization, can quickly answer to any technical problem by hiring external PV technicians. In hand of the Municipality, it would be limited by the public purchasing law.

Implementation

The Ministry of Energy proposed a business model framework, but also carried out a participative process in which the community took active part on the decisions. The implementation started before the project was financed by creating the committee and went across the construction phase. During a workshop session, the key aspects of the duties and rights agreement were discussed and approved by the majority. As a result, after a year of operation, the payment rate is about 95%, allowing us to highlight the close work with the community as the key for such success.

SESSION 5

DEVELOPMENT TRENDS
IN THE OFF-GRID SECTOR

THURSDAY, September 16

An integrated approach for powering primary health facilities in developing countries with solar technologies

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The health system of most Sub-Saharan countries consists of a primary, secondary and tertiary health care level. Each level assumes specific functions in the system. The primary level includes rural *health posts*, rural and urban *health centers*, and small *clinics*. The main tasks of these primary health care facilities are:

- to provide first aid for injured and sick persons
- to carry out initial inpatient treatment and in case of clinics also outpatient treatment and basic surgery
- to carry out preventive measures such as immunizations and maternal support
- to inform and advise the population about basic general health prevention measures

To deliver these tasks effectively and efficiently, health facilities need to be equipped with the necessary appliances and have a stable power supply. However, according to estimates, one out of four health facilities in Sub-Sahara Africa (SSA) have neither access to electricity nor basic electric medical equipment. The number and percentage of health facilities without access to power is especially high for *health posts* and *centers* located in villages and providing basic first medical aid.

Several international governmental and non-governmental organizations have therefore been supporting the electrification of health facilities in Africa with solar technologies with the objective of substantial improvements in health services.

At the same time, the failure rate of PV systems in health facilities after a few years is high. Main reasons for failure are:

- inadequate system design
- low-quality components
- poor installation quality

- shaded solar panels
- dead batteries
- little or no training of end users
- lack of load limiters or mitigation for auxiliary uses
- inadequate budget for maintenance including spare parts/replacement

The paper will present different approaches to improve the sustainability of solar installations for health facilities, with a focus on different maintenance approaches, considering the role of governmental institutions, private solar companies and the health facilities themselves. In addition, the sustainability of PV systems depends to a large degree on the effective use of equipment and on the expertise and passion of the team in the health facilities regarding medical services and regarding basic maintenance of energy systems and electric devices. Consequently, the paper will discuss how electrification of health centers and improvement of services through new equipment and training of staff can be better integrated to ensure a sustainable long-term use of PV systems and medical equipment.

Hydro Empowerment Network HPNET: What the solar mini grid sector can learn from more than 40 years of small-scale hydro experience

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Keywords: mini grids, sustainability, capacity building, economic development

HPNET's approach

The Hydro Empowerment Network (HPNET) is a south-south knowledge exchange and advocacy platform for advancing hydro mini-grids for sustainable and equitable energy access, supported by the WISIONS of Sustainability initiative at the Wuppertal Institute for Climate, Environment and Energy. Skat Foundation with its long-standing experience in creation, sharing and documenting of knowledge and in fostering technology transfer for practitioners in the global south has assisted HPNET to establish its present-day structure and is providing continuous advice. With more than 150 individual members across 19 countries, HPNET's approach to knowledge exchange leverages diverse multi-actors (see figure) and re-activates the sector's knowledge development history of over 40 years. To advance its nine thematic working groups, the network uses a 4-step process towards creating impact at the ground level – *collation* of existing knowledge products, *groundtruthing* current situation, *facilitating* collaborative exchange, and *advocating* for post-exchange action.

Hydro mini-grids: Long-proven but forgotten

Within the technologies available for mini-grids, micro and mini hydropower (MHP) has added advantages. In places where sound hydropower potential is available, its techno-economic characteristics, such as lower levelized cost of electricity, per kilowatt cost, and no need for battery storage, make it economically viable for mini grids with productive use applications as well as for grid interconnection . Because MHP hardware can be manufactured locally and maintained by local actors, MHP development imparts local skills and jobs, which can evolve into local enterprises. In addition, MHP strengthens watershed protection, in turn increasing the climate resilience of vulnerable communities in hilly regions.

With implementation starting as early as the 1970s, long before the term “mini-grid” existed, the number of hydro mini-grids in rural areas of Asia, Africa, and Latin America far exceed other types of mini-grids. In countries like Nepal, Pakistan, Afghanistan, technology transfer supported by GIZ, Skat, Danida and others over the time led to the successful establishment of local production of electro-mechanical equipment and of local know-how on planning, implementation and operation of hydro mini-grids. Today, HPNET’s knowledge exchange activities like technical trainings, practice-to-policy and sub- / cross-region workshops, supported by Wisions, allow local practitioners to access and make use of the sector’s decades of experience, promoting solutions for long-term sustainability, optimal socio-economic impact, and scalability.

Lessons learned from more than 40 years of small-scale hydro experience

The following four aspects are considered to be of utmost importance for mini-grids, be it hydro or PV:

1. <u>Local know-how</u> on the technology: intensive and persevering capacity building on:
   a. Technical, management and other relevant aspects to build up a strong local sector for component manufacturing, service provision etc.,
   b. Energy planning for appropriate resource assessment, designing of isolated systems, later integration (grid interconnection),
   c. Policy and regulatory aspects for the right switch setting (subsidisation, tariffs structure etc.)
2. <u>Energy use and energy efficiency</u>: productive use of energy ensures economic development, affordability of energy, revenues which allow for sustainable operation; energy efficiency helps to limit peak loads (different focus: e.g. hydro without storage needs “balanced” load curve, solar with battery needs to minimise required storage)
3. <u>Optimised use of available renewable energy resources</u>: avoid technology driven approaches and compare available resources (PV, hydro, biomass, wind or hybrids)
4. <u>Overall (master) plan, avoid “isolated solutions”</u>: a critical mass of a certain technology allows opens new opportunities (e.g. production of turbines, production of control systems, maintenance and service capacity), consideration of later grid-connection of mini grids to make optimal use of investment

“Zero emissions” knowledge exchange outputs

In times of global climate change, HPNET prioritizes the minimisation of its ecological footprint through virtual exchange. Although in-person exchanges have played a critical role in the development of HPNET’s thematic Working Groups, it’s follow up on-line exchange activity has synergized field practitioners, regional and international experts to generate solutions to today’s barriers and opportunities, building on 40 years of hindsight.

Haiti Renewable Energy Mini grid Program: PHARES

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Keywords: Mini grids, renewable energy, energy access, bottom-up, results based subsidy

The case of PHARES in Haiti

The Government of Haiti has set a goal of becoming an emerging economy within the next decade, facing wide poverty disparities and regular external shocks that jeopardize the country's development. This goal requires a clear vision for the energy sector, in order to promote universal access to electricity services and transform the underdeveloped, unreliable, and expensive fossil fuel–based generation mix accessible by only 45% of the population, to a modern and sustainable system.

Within this framework, the PHARES Program (Programme Haïtien d'Accès des communautés Rurales à l'Energie Solaire) was launched in September 2020 by the Government of Haiti, with the initial support of the Inter-American Development Bank (IDB) and the World Bank (WB). PHARES is implemented by the Ministry of Public Works, Transport and Communications (MTPTC), through its Energy Cell, the National Regulatory Authority for the Energy Sector (ANARSE) and the Technical Unit of Execution of the Ministry of Economy and Finance (UTE-MEF). PHARES's main objective is to increase the access of rural and peri-urban communities to solar energy and in particular to provide access to affordable, accessible and sustainable energy services, through mini grids using renewable energy, developed and operated by the private sector.

For this purpose, PHARES developed an innovative continuous bottom-up approach for the submission of proposals from eligible developers, following a transparent two-step process for the award of Results Based Subsidies based on number of connections and solar energy fraction that are implemented through concession agreements. The first step consists in submitting a Proposal Concept, aiming to learn more about the applicant's project, focusing on its overall concept and objectives. Successful applicants advance to the second step, being invited to submit a detailed Full Proposal including all the specific information required for the final evaluation and award.

The bottom-up approach of PHARES allows applicants to identify and propose the sites, located in rural or peri-urban areas and not served by the national grid. In all cases applicants must have the support and approval of local stakeholders and are encouraged to include a strategy to serve productive uses of energy and health, education, and water and sanitation facilities.

PHARES' continuous approach allows regular submission windows to be launched, open for any developer interested to participate in the Program. This new approach, has allowed to register more than 35 developers to the PHARES' platform, and to receive proposals for more than 40 sites during the first two windows opened so far. These results show the high potential for the mini grid sector in Haiti, encouraging the Program to continue with the implementation of the successful proposals, prepare future submission windows and complement PHARES with additional support mechanisms.

Figure 1 - Operating Mini grid in Haiti (Courtesy of Earthspark International)

Figure 2 - Operating Mini grid in Haiti (Courtesy of Earthspark International)

A History of Least Cost Mini Grid Design

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Keywords: Mini grids, solar, storage, HOMER, Grid extension, Solar home systems

Implications for Mini Grids of the Changing Economics of Solar & Storage

Mini grids based on reciprocating engines burning diesel fuel were the first type of electric power system over one hundred years ago. These same systems are still in use all over the world in small or remote places. This was an economically rational choice when diesel fuel was inexpensive, solar and wind power was expensive, and there was no concern about carbon emissions. This paper will show the impact of recent dramatic changes in these three factors on least cost design of mini grids.

These changes have gone through several stages and are continuing to evolve. The first stage was wind-diesel systems without storage, followed by solar-diesel systems without storage. These were relatively simple designs but had limited savings as they reduced the efficiency of the diesel generators. As solar costs continued to decline it became cost-effective to install larger solar arrays even with the resulting need to curtail some of their production.

The advent of new storage technologies, notable various lithium chemistries, is ushering in a new era of mini grid design that reduces both curtailments and diesel runtime. The paper will show the synergy and trade-offs between batteries and diesel generators, because the batteries allow the diesel generators to be run more efficiently and the diesel generators allow the use of smaller battery banks that can be managed better.

The next advance in mini-grid design is coming through improvements in power electronics with grid forming inverters that create a stable power system without the mechanical inertial of rotating equipment. This is paving the way for systems that are 100% renewable. That final step requires loads management using communication and control technologies that have not traditionally been part of power system design.

Results from the HOMER software will be used to illustrate the impact of these economic changes on system design. Although these innovations are being first developed for smaller mini-grids, their applicability is continuing to expand to ever larger systems.

SESSION 6

INNOVATIONS, PRODUCTIVE USES AND PLANNING

THURSDAY, September 16

s-@ccess

How to Design a Photovoltaic Powered Aeration System

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Keywords: aquaculture, aeration, photovoltaic aeration system

Aquaculture is an important component of the sustainable development goals. In particular, aquaculture contributes towards ending hunger, achieving food security and improving nutrition. Since the 1980s, the world aquaculture production increased from 7% of global fisheries to over 40%. With 5.8 per cent annual growth rate since 2010, aquaculture continues to grow faster than other major food production sectors. Despite this growth, the level of dissolved oxygen in fishponds is often low and undermines the water quality, which ultimately decreases productivity. An aeration system is thus considered as a suitable solution to address the problem. The objective of this article is to provide a simple method to design a photovoltaic powered aeration system. This is indispensable in intensive aquaculture, especially in rural areas where conventional electric power systems are often non-existent. Photovoltaic powered aeration system is made up of two parts: aeration and photovoltaic and they are usually designed separately. In order to realize the goals of this study, extent literature is reviewed and a GPS and an oximeter are used. Three simple equations, among others, for: sizing the aerator, determining the oxygen demand, and the efficiency for power consumption by fish emerged in the analysis. The size of the photovoltaic system is the first part to think about when designing the photovoltaic powered aeration system. This approach eliminates the problem pertaining to viability of stand-alone photovoltaic systems. The result combined two parts into one system design that interconnects them.

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REvivED Water: Innovative electrodialysis solutions for clean drinking water in Off-Grid areas

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Keywords: water desalination, brackish water, capacitive electrodialysis, stand-alone energy supply

The balance between drinking water demand and water availability has reached a critical level in many regions of the world. Especially in dry regions of developing countries people suffer from increasingly salty water sources. Regions with water shortages often are situated far from any electricity grid.

"REvivED water", a research and innovation project funded under the EU's Horizon 2020 programme in the field of 'low-energy solutions for drinking water', brings together ten partners from six European countries that will contribute to overcoming the drinking water challenge by establishing electrodialysis (ED) as the new standard for desalination.

One of the ED based solutions developed by the REvivED water project are small-scale desalination units powered by Off-Grid solar systems for the use in developing countries to get clean drinking water out of brackish water sources. The new system has the advantages of lower energy consumption, low maintenance and independence from any kind of infrastructure which is ideal for remote areas.

Several aspects were investigated during the development of the first pilot such as the pre-treatment, ED unit, post-treatment and waste management. The first prototype was constructed and tested in a laboratory in April 2018. Investigations of the pilot run and the field test in Somaliland led to the development of two further generations of the system. They include the following modules:

A) Pre-Treatment Unit: Microfiltration and Activated Carbon
   The filtration technology and activated carbon was chosen out of seven pre-treatment options due to its robustness, simplicity, and economic viability.
B) Capacitive Electrodialysis (CED) desalination unit
   A desalination unit with capacitive electrodes, new generation of ion exchange membranes and innovative stack design was developed.

C) Post-Treatment: Chlorination by electrochemical activation
A chlorine treatment of the out-coming water and for the system's cleaning purposes was chosen as the most viable option.

D) Concentrate Disposal: Evaporation pond for brine
The salt concentrate water as waste product of the system is being collected in an evaporation pond.

E) Solar Power Supply
The PV system for power supply was sized with the further developed EasySizing REvivED software.

F) Control and user interface
The system can be monitored and controlled via GSM from all parts of the world.

Figure 1: Schematic overview of the system

For the first field test a salted well in the desert of Somaliland was selected. The PV powered pilot plant was installed in May 2018 in the village Beyo Gulan to collect data from the operation under the Somali sun. Seven additional pilot systems of generation 2 and 3 are installed in 2019 in various African countries and in India.

The presentation will give an insight into the technology used, the performance of the pilot systems in the field and the experiences collected during the field tests.

Figure 2 and 3: Field tests with REvivED systems in Somaliland and Djibouti

Aknowledgement:

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Designing Solar PV for Topping up Energy of an Oil based Solar Thermal Collector for Cooking Application

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Key words: solar cooking, solar PV design, thermal solar collector

Biomass represents the major source of energy for heating and cooking in many countries of Sub-Saharan Africa. In doors pollution related to biomass burning is a serious public health problems in this region. Biomass resources are depleting in many regions of the continent which make women and children walk long distances in its search. Solar cooking can be one of the solution form this problem. Indirect solar thermal systems for cooking enable the cooker to prepare the meals under the shade and at any time of the day. It is in this context that an oil based solar system for cooking application is being developed. So far a solar thermal collector has been successfully tested. The output temperature for passive circulation is around 140 oC. Solar PV system has been designed to increase temperature of the working fluid to the desired cooking levels. This paper presents the results of this study in its technical aspect.

Peltier cooling in SHS systems

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Keywords: Solar cooling

Access to cooling brings a wide range of benefits to rural communities: Perishable goods can be stored longer; additional income can be generated, by selling cooled drinks and new business ideas such as producing fruit juices or yoghurt can be realized.

Unfortunately, is cooling, besides cooking, one of the most energy intensive services. Also, can cooling not be accomplished by any inferior technologies such as fire.

Most available refrigerators work with compressors. Fosera has research this technology for the past 2 years and tried to launch a product to the market. Within this process we found several severe disadvantages, which make this technology for the current market situation an inadequate choice. Compressor coolers are expensive, difficult to transport, due to the easy inflammable refrigerant and weight and hard or even impossible to repair within a set-up of local repair centers. In addition are the refrigerants and oils used in the compressor extremely harmful to environment and the climate.

An alternative technology is Peltier, a semi-conductor-based, cooling technologies. Peltier coolers are by factor 3 - 4 cheaper and low in maintenance. They can be transported easily and have, beside the fans, no mechanical moving parts. The repair and assembly of Peltier coolers is comparatively simple and can also be done directly on site. The Peltier coolers are also much more environmentally friendly and quieter in operation. Although Peltier coolers are smaller in size, they do meet the demand and spending ability of Tier 2 electrification customers.

The downside of Peltier is clearly the lower efficiency compared to compressor refrigerators.

This lower efficiency can be compensated by dynamic power control which converts available PV energy during the day into cold which can be stored in a phase change material for direct thermal storage to overcome the night. This will avoid strong battery draining during the night and reserves enough energy for other applications such as light, phone charging and TV.

Fosera develops and produces solar home systems as well as off grid appliances such as lamps, TV´s, radios or fans. Through this activity, Fosera is well integrated in the off-grid solar market and has an established, reliable network of customers, partners and repair centers.

Fosera has its own production facility in Thailand where the products are manufactured. Ideas and prototypes can thus be quickly converted into mass production and distributed via our existing network.

Since 2012 Fosera deals with the idea to use Peltier elements in combination with off-grid solar systems. In October 2016 the Fosera Spin Off Nexol was founded, which develops photovoltaic powered Peltier water heaters.

MIA
Made in Africa

Solar Lamps and Jobs for Africa

Prof. Dipl.Ing.Peter Adelmann; Manuel Götz; id-eee Institute; Ulm; Germany

Solar Lamps have been promoted since long time to replace candles and kerosene lamps. A lot of advantages such as lower cost, less indoor pollution and lower risk for fire have been proven. Nevertheless the market for these lanterns does not develop as fast as expected. One of the key reasons is the missing local service for these products. In the rough rural environment there is a high chance that parts of the lamps break. Most of these failures are not a classical case of warranty. And if there are cases of warranty there is in most cases nobody who can handle the repair or replacement.

At the same time lamps, powered by disposable dry cell battery are booming. These lamps solve some of the above mentioned problems, but they create new problems at the same time. Main problem is the huge amount of poisoning waste which come from used dry cell batteries. There is usually no recycling or even garbage collection for these batteries.

To prevent such problems the MIA lantern has been developed. The concept of this product is to use local assembly and to move big part of the value chain to the country where the product is needed.

Technology

A comparison between different basic lamp technology has shown that the least cost option would be a concept based on a single NiMeH accumulator. Advantage of this battery is its robustness and the fact that a charge controller can be prevented [1]. The ecological impact of these batteries has be analysed in a separate study [2]. Due to the low voltage of this battery type, a DC/DC converter is needed to provide a voltage high enough to operate a high efficient white LED. Except the LED all components are selected as “true hole”-components to allow local soldering. A PET-laminated solar cell allow more than 5 years of operation.

Mechanical components such as the housing can come from local sources.

The lamp was designed to provide a luminous flux of above 20lm. This is the same luminous flux of a kerosene lamp. Due to the fact that LED provide directed light. The illuminance of a LED lamp (measured in lux) will be several times higher.

At higher quantities (>1000 units) the kit can be delivered to Africa below 2$.

Advantages

Main advantage of the concept is, that local assemblers can maintain and repair the product. Any component can be replaced. The local assembly ensure as well the availability of spare parts.

Another important advantage is the fact that most of the value is generated locally. In addition transportation cost are significant lower compared to finished products. Local assembly, maintenance and service create local jobs, income and development.

MIA Project

The project is designed as an open source project. The local companies and other developers are invited to make adoptions and modifications.

Diagrams and Pictures:

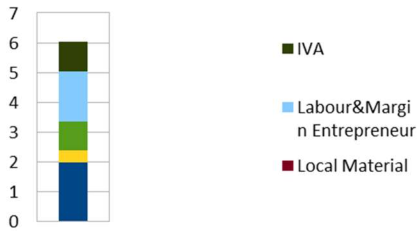
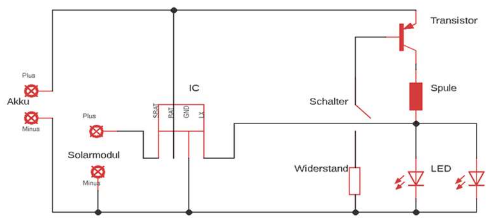


Diagram 1: Cost (in $) for a local assembled MIA lamp



Picture 1: Circuit Diagram of the lamp

Picture 2: Assembled lamp; as housing a jam jar is used; a tilt switch (from mobile phone) allow switching by turning the lamp upside down.

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Smart Solar Off-Grid in Belize

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Keywords: Rural Electrification, Off-Grid, Smart-Grid, Belize

1. Context

In Belize in Central America about 50 rural villages do not have access to electricity. In its Sustainable Energy Roadmap the Government of Belize has committed itself to achieving universal access to affordable, modern energy services by 2030. As the extension of the national grid to these remote and often difficult to access villages is costly and logistically challenging, the Ministry of Public Service, Energy and Public Utilities (MPSEPU) has identified rural electrification through solar off-grid systems as an integral component of its Sustainable Energy Roadmap. In order to receive up to 5 million EUR of financial support through the EU, the MPSEPU was required to first provide a proof of concept.

2. Project Partners

In close cooperation the German **cdw foundation**, the Belizean company **SESB Solar Energy Solutions Belize Limited** and the Swiss consultancy firm **ZENNA AG** designed and piloted a Smart Solar Off-Grid System as a proof of concept for such an off-grid electrification approach. The project was primarily financed by REPIC, the Belizean Government, the British High Commission in Belize and the cdw foundation.

3. Site Selection

The MPSEPU selected the remote village of La Gracia, a farmers' community located in the Cayo District at about 8 miles away from the national electricity grid. In 2016 the village consisted of 45 households, 2 churches, a school, a water board and 2 shops.

4. System Design

The Smart Solar Off-Grid system was engineered in 2016 and installed in 2017. The smart grid is a containerized hybrid mini-grid consisting of a 24.48 kWp PV-system, 24 kW of battery inverter power and a 22 kW back-up LP-Gas Generator.

Photovoltaic (PV):	24.48 kWp
Surge Load:	40 kW / 3 seconds
Continuous Load:	24 kW
Power Storage:	55.2kWh by 50%DoD
Phases:	Split-Phase 120/240VAC 60Hz
Performance:	Average 100 kWh/day

Power is distributed over 6 power towers located throughout the village. Smart energy meters at each power tower connect the households to the Smart Grid through underground wiring. The meters manage the household energy consumption in accordance with the actual energy produced as well as the battery charge level. They distribute energy on a pre-paid basis and allow for the control of the different users' energy demand.

Category	Energy Daily Allowance per Household	Peak Capacity Per Household
Residential	3000 Wh	Day 1000 W Night 500 W
Commercial	7000 Wh	Day 2000 W Night 1000 W
Shop Plus	7000 Wh	Day 2000 W Night 1000 W

5. Ownership and Operation

After conducting a technical test phase from May 2017 to April 2018, the ownership of the Smart Solar Off-Grid System was officially transferred to the Belizean Government on May 1st, 2018. Since then Belize Electricity Limited, the national distributor of electricity, has been operating the system successfully.

6. Next Step: Replication

In line with its vision of universal access to energy by 2030 the Belizean Government has dedicated itself to replicating the Smart Solar Off-Grid Modell in other rural regions. As of June 2019 the MPSEPU and the cdw foundation are negotiating terms to jointly realize the Modell in a second rural village in Belize.

Solar cooling systems for agricultural value chains

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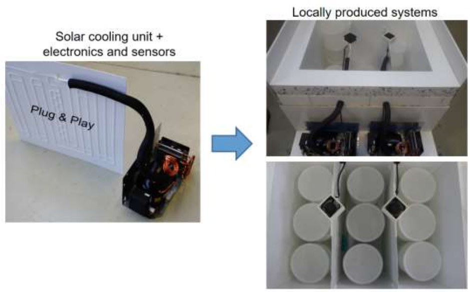
Keywords: Cooling, Refrigeration, Agriculture

Introduction

Based on the outputs of recently field testing projects, the University of Hohenheim currently supports the use of “cooling units” instead of “cooling systems” as strategy to reduce the final price of the technology while creating specialized jobs locally. By following this approach, high-tech components such as cooling units are imported while the assembling of insulation-boxes or cooling rooms is carried out locally. This way, entrepreneurs and local companies have the possibility to adapt the technology to the local market and offer distribution and maintenance under their own product brand. In the frame of a current on-going project funded by Powering Agriculture (GIZ), several example systems were developed for different cooling applications for the agricultural sector.



Example systems

A solar-powered cooling unit has been developed which allows a significantly reduction of transport cost due to compact shipping size. It is ready to use, filled with natural refrigerant R600a and in most countries able to be imported duty free as an industrial component. Local companies adapt the final cooling systems to different sizes and applications while having a business advantage against imported cooling systems from abroad. The same cooling unit model is applied for different applications such as Refrigerators, ice makers, milk cooling systems or cold rooms. The systems can be scaled up with additional cooling units and easy to repair and recycle due to the fact that insulation boxes and cooling units can be unassembled at any time.

In combination to ice-storage concepts, the presented example systems are suitable for the production of ice, cold air or cold water. All systems are suitable for direct connection to PV panels. The economic feasibility of electrical batteries is assessed through a tool box able to design the solar system in dependence of cooling demand and weather data.

Promotion strategies

The presented example systems are promoted through following measures:

- Capacity development through trainings courses (so far in Kenia, Mali and Germany, 150 participants in 2019)
- Identification of promising partners and value chains (So far implemented for ice-makers for fishers, Milk Cooling in cans and tanks, water based meat cooling, mushrooms and potato refrigeration in cold rooms and mango cooling in battery free refrigerators)
- Design and construction of local prototypes
- Sustainable pilot testing and maintenance (100% local)
- Willingness to pay assessments through rotation of the system and PAYG (Donations are avoided)

Conclusion

Refrigeration is highly demanded by farmers and cooperatives in rural areas of the tropics and subtropics. However, the local adaptation to the value chains in the local context plays the most important role for a successful introduction of solar cooling solutions.

Reliability evaluation of mini-grids considering protection issues

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Keywords: Mini-grids, protection, reliability

Mini-grids are in considerable expansion in rural areas of developing countries. They have the potential to provide electricity to millions of people and the use of renewable energy resources provide valuable benefits in terms of cost and environmental impact [1]. However, without a possible connection to the national grid, these power systems are fragile and can encounter frequent interruptions if not designed properly.

Protection schemes of rural mini-grids are usually based on conventional overcurrent devices. An important criterion to take into consideration when designing protection is the level of short-circuit current available from generating sources. The ability of renewable resources, such as PV and wind generators, to feed short-circuit currents is very limited since they are interfaced through power electronic converters with current limiters. A large integration of these power electronics interfaced sources will lead to protection issues. For mini-grids, reliability analysis is often restricted to evaluating generation adequacy. Few researchers have attempted to consider protection schemes when evaluating reliability of power systems [2].

This research paper presents a method developed as part of a PhD collaboration between the company Entech Smart Energies and the research laboratories LE2P Energy Lab and CEA Tech. The method is based on a dynamic simulation of the mini-grid to predict operational conditions (cf. Table 1) and evaluate the reliability of the protection scheme. Two causes of protection failure are investigated:

- Protection insensitivity in case of insufficient short-circuit level to trip protection devices
- False tripping

The first failure mode occurs when short-circuit current is lower than the protection trigger and will lead to a selectivity issue as a total blackout may be encountered when only part of the mini-grid is meant to be disconnected. The second failure mode occurs when normal operation current is higher than the protection trigger and consumers are disconnected, although the network is in a healthy condition. A simple test system including photovoltaic arrays (PV), diesel generators (DG), and electrical storage (ESS) is presented in Figure 1. **Figure 15** shows how the two failure probabilities are evaluated. The protection trigger current is modelled with a normal distribution around the mean setting value to consider tripping error, line currents during normal operation are obtained through load flow simulation and short circuit currents are calculated according to IEC 60909.

Operating conditions 1 & 2 where the mini-grid is solely fed by power converters are critical in terms of short-circuit current level and have a high risk of insensitivity as shown in Figure 2. False tripping also represents an important risk if insufficient margin is taken in setting protections.

When integrated in the design phase, this method can help developers size generation and conversion for a secure operation of the mini-grid.

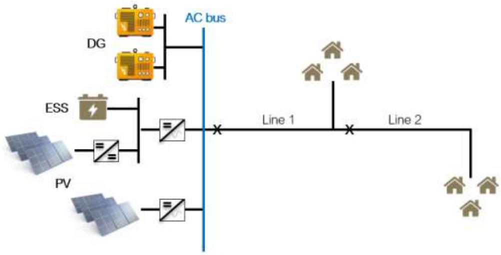

Figure 14: Mini-grid test system

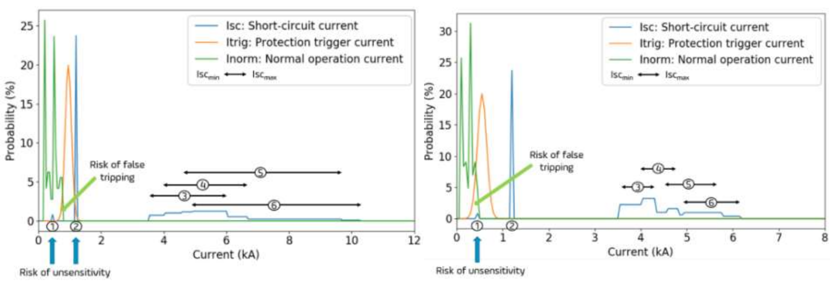

Figure 15: Illustration of protection failure probabilities for distribution line 1 (left-hand graph) & distribution line 2 (right-hand graph)

Table 1: Explanation of operating conditions numbered in Figure 2

Operating condition	Percentage of occurrence (%)	GE1	GE2	Battery inverter	PV inverter
1	0.8	-	-	√	-
2	23.7	-	-	√	√
3	35.8	√	-	√	-
4	15.9	√	-	√	√
5	14.4	√	√	√	-
6	9.4	√	√	√	√

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Development of a Monitoring and Evaluation Framework to Generate Data-driven Load Profiles for Rural Households Powered by a Solar Hybrid Mini-grid

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Keywords: Hybrid Renewable Mini-grids, Rural Household Load Profiles, Energy Access, Social Development, Smart Energy Management

Hybrid renewable mini-grids have emerged as a viable solution for providing reliable, environmentally friendly electricity to remote communities. An affordable and grid-quality supply of energy can open new possibilities for socioeconomic progress.

As part of a joint project between South Africa's Eastern Cape province and Germany's state of Lower Saxony, with funding from BMZ (Federal Ministry for Economic Cooperation and Development) through GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), a solar (photovoltaic) hybrid mini-grid was designed and developed in the municipality of Upper Blinkwater in Eastern Cape, South Africa for a rural community of 67 households with 90% living off of social grants and no access to the main national grid.

Successful implementation of mini-grids requires the right technology, access to financing and consumer-friendly payment system, an appropriate regulatory environment, social facilitation, institutional implementation, environmental impact evaluation, human capitalization and training, and implementing a robust, reliable, and sustainable Monitoring and Evaluation Framework (MEF). The aim of this work is to design a systematic approach to the development of a sustainable MEF for hybrid renewable mini-grids by integrating cutting-edge technologies and SMART methods in a scalable platform of replicable solutions towards connecting the mini-grid with diverse stakeholders, including governmental organizations, investors, utility operators, consumers, research institutes, and universities with enhanced observability of both generation and consumption profiles.

In the first step the main features of MEF and the integrated components are specified. In the second step a set of Key Performance Indicators (KPIs) are developed through a technical workshop with all the stakeholders by first defining two types of data sources, energy and non-energy and then parametrizing the mini-grid accordingly. In the next phase KPIs are categorized into five domains including, technical, operational, financial, social, and environmental according to specific need of each stakeholder for monitoring and evaluation purposes. In the last step a data flow scheme is designed and the appropriate smart metering devices, telecommunication technologies and software modules are integrated in order to transfer the system data.

The MEF provides the opportunity to streamline the flow of real-time energy data (generation, consumption, and storage) from the system to generate accurate and high-resolution data-driven load profiles for rural households or communities. These profiles are used for studying and analyzing the evolution of demand and making ongoing design optimization. These profiles will be useful as a reference for mini-grid researchers and developers active in Sub-Saharan Africa. At the same time, the interrelation between energy access and social development will be studied and analyzed.

The future plan is to integrate machine learning methods to establish a correlation between renewable energy forecasting, household load profile generation and the social development progress to further improve the study

Exploring the nexus of mini-grids and digital technologies

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Keywords: Digitalisation, Mini-Grids, Sub-Sahara Africa

Potentials, challenges and options for sustainable energy access in Sub-Sahara Africa

Over the past years, the mini-grid sector has seen an increase in the use of digital technologies while at the same time digital innovations transform the socioeconomic landscape in Sub-Saharan Africa. In our study, which bases on literature review, expert interviews and insights gained from a stakeholder workshop, we provide an overview of today's status of digital technologies in mini-grids and their potential to optimise processes, reduce costs and improve services for the consumers. We also identify the challenges and risks related to the new technologies, in particular with regards to privacy, data security and social impacts on rural communities.

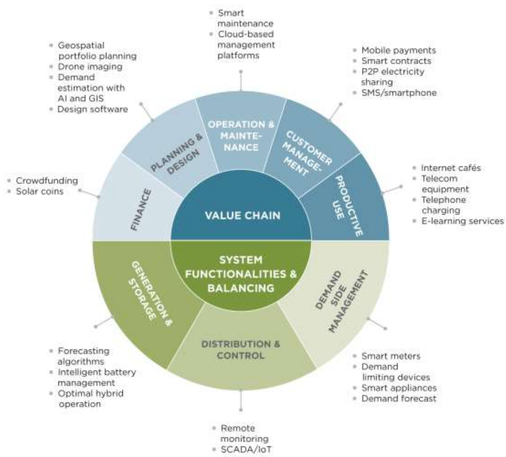

Figure 1. Application areas of digital technologies in mini-grids

As shown in Figure 1, our analysis distinguishes between two levels of applications for digital technologies in mini-grids: (1) the level of technical functionalities and system balancing, including generation and storage, distribution and control, as well as demand side management; and (2) the level of the mini-grid value chain, which includes finance, planning and design, operation and maintenance, customer management and productive use of electricity.

Across these applications, digital technologies offer manifold opportunities. For example, drone imaging and demand projection using artificial intelligence and geo-information systems (GIS) can improve planning and sizing of mini-grids. Remote predictive maintenance could reduce downtimes and costly trips to the mini-grid site. Furthermore, integrated mini-grid solutions that provide access to the Internet and digital learning materials can foster the development of productive uses and generate new income opportunities in rural areas.

The study also reveals challenges and risks of using digital technologies in mini-grids in Sub-Saharan Africa. Besides privacy, data ownership and data security issues, research has shown that the application of digital technologies could deepen existing inequalities within a community. To prevent that scenario, particularly vulnerable groups, e.g. low-income families or women, should be involved in the planning so that their needs are accommodated early on. Economic decisions, for instance tariff setting, need to be communicated transparently whereas payment systems should be transparent, traceable and user-friendly.

Policymakers, donor organisations and technology developers are encouraged to consider these aspects and the specific local contexts in which the technologies are used in order to foster the appropriate and purposeful application of digital technologies in mini-grids.

Interdisciplinary Analysis of Renewable Energy-Based Mini-Grids in Namibian Remote Areas – An Overview on the PROCEED Project

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Keywords: mini-grid, remote village power supply 2.0, decentralised electricity transition, interdisciplinary approach, payment business model, validated algorithm / living-lab

Background

In Namibia, about 28 % (2016) of the rural population has no access to electricity [1, 2]. Due to its low population density and a distributed settlement structure, the country faces particular challenges in the electrification of remote areas. Despite the abundant availability of solar and wind resources, the share of renewable energies (RE) in Namibia's energy consumption is less than 20 % (2018) [3]. Against this background, the German-Namibian joint project PROCEED (Pathway to Renewable Off-Grid Community Energy for Development) aims at the interdisciplinary analysis of options for an efficient, sustainable and renewable energy-based power supply in Namibian remote areas using mini-grids (MG). Using the example of different regions in Namibia, the project consortium conducts case studies at existing remote MG (cf. Figure 1), investigating social and community structures, societal perceptions, legal, regulatory and economic conditions as well as the energy technologies applied.

Figure 1: PROCEED`s reference objects in Tsumkwe (left) and Gam (right) in the Otjozondjupa region in northeast Namibia are currently the country's largest mini-grid systems (images: Fabian Junker, THI)

The Project in Brief – Innovation through Interdisciplinarity

Aiming at effective implementation of the project, the PROCEED project is organised in four work packages focusing on *society*, *economics*, *technology* and *sustainability*. Researchers from University of Bayreuth will conduct interviews and data surveys in order to analyse geographic and sociocultural conditions (*mini-grid communities*) for increased power generation by means of off-grid hybrid energy systems. Regarding the topic of *mini-grid economics*, University of Applied Sciences Neu-Ulm is investigating options for a cost-covering tariff and payment system for locally organised hybrid energy systems and develops suitable business models for the commercial use of the generated electricity. The determination of consumption profiles and building loads as well as the optimal design of hybrid systems based on RE are the focus of research in *mini-grid technology*, which is performed by the Institute of new Energy Systems at THI and IBC Solar AG. By formulating practice-oriented recommendations for action and developing training program concepts based on the outcomes of the three main research areas, the fourth focus, *mini-grid sustainability*, will enable the sustainable utilisation of project results at national and supraregional levels.

In addition to the PROCEED`s interdisciplinary approach, the consortium attaches particular importance to the close cooperation with local partners in Namibia. The long-term experience of PROCEED´s Namibian partners (e.g. Namibian Energy Institute, Alensy Energy Solutions (Pty) Ltd and the Renewable Energy Industry Association of Namibia) with the technical and social conditions in the local environment is thereby the basis for effective solutions for MG systems. At the same time, ongoing exchange with partner institutions at the national (Ministry of Mines and Energy) and regional (SADC Center for Renewable Energy and Energy Efficiency) level ensures that the outcomes are tailored to Namibia`s energy policy agenda. As a result, the findings obtained from the PROCEED project constitute a valuable basis for the long-term promotion of RE systems, for instance by the Hanns Seidel Foundation Namibia based in Windhoek.

The project is funded by the *Federal Ministry of Education and Research* within the funding scheme *Client II* (International Partnerships for Sustainable Innovations); Funding Code: *03SF0570A-D*

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SESSION 7

ENERGY FOR LOCAL DEVELOPMENT AND LIVELIHOOD

FRIDAY, September 17

s-@ccess

Hybrid mini-grids for healthcare and livelihoods opportunities in humanitarian settings: The case of Mahama Refugee Camp

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Keywords: humanitarian, solar, mini-grids, healthcare, livelihoods

The hybrid mini-grid in Mahama Refugee Camp

Mahama Refugee Camp in Rwanda typifies many situations of displacement in sub-Saharan Africa: access to energy is severely limited and higher tiers of electricity services are available only to the camp authorities such as UNHCR and other NGOs[3]. Until recently a diesel generator supplied the health centre but, similar to many other camps, power was not continuous and the system was expensive to operate. Furthermore camp residents lack access to sufficient electricity for productive livelihoods activities and other opportunities to use electricity to generate incomes are severely limited. Meanwhile, off-grid solar energy technologies offer a pragmatic solution to provide sustainable energy in the camp both to reduce the reliance on fossil fuel generation for institutional users and extend the benefits of high-quality electricity to entrepreneurs[4].

MeshPower Ltd., the largest mini-grid provider in Rwanda, has integrated solar and battery storage capacity into the existing diesel system that supplies the health centre in Mahama Refugee Camp. This was done in two stages: the first installed the sustainable energy equipment for the health centre to offset the usage of the diesel generator, and the second extended the electricity distribution network to the nearby marketplace to provide power to refugee businesses.

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Quantifying the system performance and its impact on refugee livelihoods

We will present the findings of our techno-economic, environmental and social impact investigation of the hybrid mini-grid system. Using our open-access mini-grid simulation and optimisation model CLOVER[5], combined with energy usage data collected using MeshPower's innovative remote electricity monitoring systems, we will evaluate the technical, economic and environmental performance of the mini-grid. This will include its ability to meet the demands of both the health centre and refugee businesses and will quantify the financial and greenhouse gas emissions savings resultant from installing the solar and battery storage equipment.

We will also present the emerging findings of our socio-economic monitoring and evaluation that investigates the socio-economic impacts of new access to electricity in the nearby marketplace facilitated by the mini-grid. Particular focus will be given to the types of refugee enterprises that now have access to power, their electricity usage, increases in income and their potential to create jobs for other camp residents.

Evaluating the private sector delivery model in humanitarian settings

Using this project as an example, we will examine the opportunities and challenges of private sector delivery models for hybrid mini-grids in situations of displacement. We will quantify the opportunities for financially and environmentally sustainable provision of electricity and discuss the lessons for academia, the private sector, and humanitarian

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Pay-as-you-go Solar: UGANDA

A Potential Energy Reality in the West Nile Context?

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Keywords: PayGo, Segmentation, Financing

Over the last decade, the humanitarian community has increasingly recognized the importance of addressing energy needs in emergencies, but there is not yet broad agreement on how to do it. This paper examines refugee access to power and lighting in Uganda, where 89% of 1.4 million refugees have unmet energy needs. The reality is that aid resources to meet these needs are scare and dwindling – so pursuing investments with long-term impact is a priority. The paper identifies investment opportunities that could lead to a future where refugee and host communities reap the benefits of high quality solar systems. We identify opportunities to make that vision a reality with collaborative commitment from humanitarian actors, local government and the private sector.

Refugee settlements in Uganda's West Nile region offer an important test case for PAYGo's ability to reach low-income and sparsely distributed rural populations. With clear energy access deficits and humanitarian and private sector investments in both energy access and necessary supportive infrastructure (including mobile networks), there is justified interest in establishing whether refugee and host community needs can be met using PAYGo solar solutions. This research allowed us to map current access to PAYGo products and services within refugee settlements and explore local consumer, merchant and market actor attitudes towards PAYGo in refugee settings. Merchants were carefully studied as both consumers of energy for productive purposes and potential sellers of PAYGo and other Off-grid Solar (OGS) products within the markets they serve.

This research found a near total absence of PAYGo products and services within refugee settlements, where use of solar energy is limited to larger business owners. There is practically no knowledge of PAYGo payment options nor OGS quality standards among local merchants and potential consumers. Unreliable mobile money services pose further challenges to PAYGo delivery. While lighting and power is a high priority across all consumer segments within the refugee settlements, there is a mismatch between what refugee and host community members want and can pay for in energy products, and what is currently on offer from PAYGo suppliers. Current PAYGo products are largely too expensive, and require repayment periods that are too long for most refugee and host consumers. 75% of respondents would take a PAYGo loan, but requested shorter overall payment periods and flexibility to accommodate inconsistent income streams (particularly for farmers or businesses dependent on farmers' income due to seasonal harvest periods). Despite its promise, these challenges mean that PAYGo solar is not yet a reality for refugee communities in the West Nile.

Despite the challenges, we identified opportunities to create functioning OGS markets that are accessible by refugee communities in the West Nile and leverage both PAYGo and alternative financing mechanisms, for different consumer segments.

Study of photovoltaic energy for the reduction of Moroccan households energy poverty

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Low cost patterns of Photovoltaic (PV) systems is breaking the traditional market with the growth being in some countries exponential [1], whereas in other countries with a big potential the energy policy introduces slowly the penetration of PV systems in the market. Morocco imports more than 90% of the energy and has installed around 1 GW of PV related capacity and aims to reach 5 GW by 2030. It still far from European countries renewables' thresholds, for instance, Spain installed 5 GW and aims to reach 40 GW by 2030. This study highlights different embedded opportunities along with energy saving strategies for small consumers. The PV systems will pay back for off-grid systems in 10 to 13 years.

Electric prices in Morroco and the EU

Despite the reduced PV prices in the entire world, this decade Morocco has increased the bill of the stakeholders, making it similar to Europe, and left growing numbers of families with difficulties to afford that involving thousands of cases of Energy Poverty. Morocco's minimum wage is around 280 € per month in the public sector, around 240 € per month in the private sector and 6.5 € per day for agricultural workers. The median salary is 2197 € per month, which means that half (50%) of the population are earning less than 2197 €. Salaries in Spain range between 426 € per month (minimum salary) to 3146 € per month (medium salary). The price of electricity was around 0.088 € per kWh in 2014 [2]. For comparison, the average price of electricity in the world for that period is 0.13 €/kWh (0.14 U.S./kWh), and in Spain 0.15 €/kWh (without fix term and taxes). That's means for a family living from minimum wages the electricity costs more than 6% of the income.

Table 1. Sample of Electric domestic consumption in Morocco.

	Power (Fix term)		Consumption (variable term)		Total	Total energy price
Household	kW	€	kWh	€	€	€/kWh
Small	4.6	224.0	1274	210.43	434.42	0.34
Medium	5.7	277.5	2548	420.87	698.41	0.27
Large	9.2	448.0	7200	1189.19	1637.15	0.23

The most efficient or poorest houses are paying more for energy, especially if the total cost and the energy consumption is taken into account (table 1).

Poverty risk is inversely related to the access to modern energy services, although improving access is only one factor among others to reduce energy poverty.

PV systems will be crucial in developed and growing economies so as to reduce the price of energy, and to increase energy access to the poorest people. Some real cases have been studied according to EUROSTAT methodology taking into account the solar radiation at latitude 34º. The electric storage with batteries goes from 200-2000 €/kWh (depending on the technology lead-acid or li-ion).

Morocco gives priority to developing renewable energy and sustainable development. With abundant solar resources (a potential of 2 600 kWh/m²/year and a PV production of 1680 kWh/kWp) and a strategic position at the heart of an energy hub (Connexion with Spanish Network through two electric lines 400kV/700 MW).

Table 2. Cost in € of three different off-grid PV systems (prices and qualities)

Household	Peak Power (kWp)	Cost of the PV	Cost of the HIBRID INVERTER	Cost of the BATERIES €	Cost of the Auxiliar System. €	TOTAL €
Small	0,81	486	300	1000	600	2386
Medium	1,62	972	600	1500	2000	5072
Large	4,05	2430	1200	3000	3000	9630

Table 3. Estimation of the actual cost and the off-grid cost for different consumers.

Household	Total kW	Energy Cost[€/year]	Electric cost[€/kWh]	Cost Production Off grid (20 years) €/kWh	Cost Demand off grid (20 years) €/kWh	Pay-back years
Small	2,6	197,34	0,15	0,074	0,09	12
Medium	5,7	405,68	0.27	0,078	0,10	13
Large	9,2	994,4	0.23	0,059	0,07	10

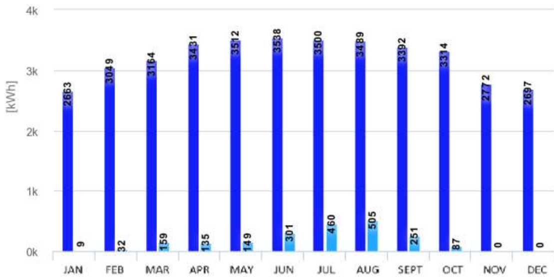

Figure 1. Energy production in kWh for a 810 Wp Small off-grid PV in Rabbat. Source; PVGIS2017 Blue; PV production. Cian; Excess energy.

Conclusions.

Moroccan electric system needs a great change to avoid the raise of energy poverty. PV systems in Morocco and other Mediterranean countries can help to reduce an amount of 50% from the energy cost, and avoid the increase of energy poverty risk.

The cost of electricity is higher every year for small consumers, when the PV off grid systems is cheaper. PV will be crucial to reduce the energy dependency and poverty in Morocco.

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Renewable energy in humanitarian settings: a blueprint

Topic 4.5 – Refugees and host communities

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Nowadays, the world is witnessing an unprecedented level of displacement. According to UNHCR, about 70.8 million people are forcibly displaced worldwide and among them are nearly 25.9 million refugees. Most refugees depend on energy resources for use in everyday life that pose enormous risks to their safety and well-being. UNHCR and its partners rely highly on conventional polluting diesel generators to provide refugee settlements with electricity for common every day needs, such as lighting, as well as to operate the infrastructure and services in the settlements. Apart from the environmental and health-related drawbacks, this also results in high costs.

For this purpose, IRENA supported UNHCR in addressing the issue of efficient, clean, affordable and reliable energy supply in four refugee settlements. The main objective of this collaboration was to assess the current and expected energy consumption in four camps and identify the ideal renewable energy solutions that would provide the refugees with clean, reliable and affordable energy for their everyday needs and concurrently reduce the exorbitant cost of diesel.

The energy assessments were conducted at the compounds of the various humanitarian organisations present in the camps as well as at the various service points (schools, health centres…etc). The assessments also included a survey for the beneficiaries at community level and household level in order to understand the refugees' point of view in terms of energy consumption and particularly for Ethiopia, also regarding the problems with the neighbouring community for the collection of firewood for cooking.

This paper encompasses the study conducted by IRENA in collaboration with UNHCR and the various RE solutions that were identified after the detailed energy assessments which were conducted in Q4 2019. The data collected during the energy assessments by the consultancy entity was used to perform techno-economic analysis of the various locations in each camp with mini-grids modelling software HOMER Pro and solar PV design tool Helioscope. Both tools were used to design the ideal least-cost RE solution for providing the refugees with inexpensive, reliable and clean energy, and to reduce the diesel consumption for each settlement. The different solutions which were identified include solar PV mini-grids, solar home systems (SHS) and solar water pumping solutions.

SESSION 9

INTEGRATED CONCEPTS AND ENERGY MANAGEMENT

FRIDAY, September 17

Energy Management in Offgrid Systems

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Keywords: Energy Management, Offgrid systems, monitoring of hybrid systems, Studer-Innotec, data analysis, ISO 50001, monitoring portal,

Offgrid systems are often relatively complex to implement. There are specialists who size and install them, then those are given to their users who often do not have specific knowledge about the operation of such systems. These energy systems are nevertheless of great importance for end-users who are relatively powerless in front of technical aspects.

One observation made is that a structured monitoring is often sorely lacking. Although information is available through complex measurement systems, the analysis of these data is missing to pull meaning out of it. The next step is also often missing: take corrective action on the base of the measured data. The initiators of these projects install high-tech devices, online databases and many other technological gadgets, but the systematic analysis of the information collected is lacking. Worse, the mass of recorded data, sometimes GB of data, requires complicated tools beyond the reach of the non-specialists. Simplification is needed to make energy monitoring accessible to real users of offgrid systems.

A proper energy management can provide significant assistance in this context. This paper presents the methodology to use those data and practical examples in mountain huts in Switzerland. The methodology is strongly inspired by ISO50001 as used by ESCOs. This was adapted to the offgrid world and applied in various projects. Improvement on energy consumption was up to 30%. This experience with energy management have strongly modified our view with after sales services of offgrid system and now influences the development of new monitoring tools provided by Studer-Innotec.

The first step of the methodology is to set the will and the capacity to follow energy in the long term. The second step is to make a clear review of the energy use with the help of measurements. For this, it is important to present the different situations clearly: summer/winter, occupied/not occupied. The first energy review gives the reference situation and every year, a comparison to this is done. Then a continuous improvement circle is set up: fix improvement target, take actions, measure the results with the monitoring system, review improvements and set new goals.

The improvement in energy systems can be energetical, in term of saved kWh, but also financial with an OPEX optimization, or organisational: to diminish the worries of owner about the troubles with energy systems.

At the age of big data, we have today the tools to monitor installations. There are Gigabytes of sleeping datas in hard drives and SD cards and we have to learn to exploit it. The manufacturer of devices (inverter, solar chargers,…) have to provide the data but also to help to understand it. In that domain there is large space for innovation, mixing management tools, data analysis and UX.

Integration of Electro-Mobility Solutions into Off-Grid PV Systems for Sustainable Development of Rural Areas in Sub-Sahara Africa

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Keywords: off-grid, e-mobility, Sub-Saharan Africa,
stand-alone PV systems, simulation

Background

Today, rural communities in Sub-Sahara Africa (SSA) lack access to adequate and reliable transportation. The majority of SSA's rural settlers rely on bicycle taxis, animal-driven carts and old vehicles that mostly run inefficiently at low speed with high fuel consumption and greenhouse gas (GHG) emissions. Most of the young people walk over long distances to schools or tend to use poor transport services, which contributes to late enrolment or early drop-out (Bloemen, 2018). Women and children have to walk over a long distance to fetch (untreated) water from the lakes or wells for domestic usages. As a result, this makes them vulnerable to diseases, poverty and gender inequality (Sewell, 2016; Porter, 2014).

Compared to conventional systems (typically diesel generators), stand-alone and / or hybrid PV systems provide a reliable electricity supply at reasonable costs. Complementing off-grid PV systems with battery electric vehicles (BEVs) such as electric boats, cars, and (cargo) bikes can be a socio-economic development strategy for SSA's rural communities (Mueller and Mueller, 2014). As the energy for operating BEVs is generated within the rural communities, a further development of the local economy can be achieved.

Current status and perspective of Water-Energy Hubs

Currently, so-called *Water-Energy Hubs* (WE!Hubs) operated by *We!Hub Victoria Ltd* (owned by the *Siemens Stiftung*) enable the Kenyan population around *Lake Victoria* access to sustainably generated electricity and clean drinking water. PV-generated electricity is used for water purification as well as for charging special, floatable lanterns for night fishing. In order to expand the effective radius of the *WE!Hubs* and to open up new recovery paths for the generated electricity, the *Institute of new Energy Systems* together with the *Siemens Stiftung* aims at integrating a holistic e-mobility concept into the existing infrastructure of the *WE!Hubs*. The mobility solutions range from electric cargo bikes and vehicles (for the distribution of purified drinking water and local transportation) to electrically operated fishing boats.

Figure 2: Typical *WE!Hub* located at Lake Victoria. © *Siemens Stiftung*

Methodology

The *Institute of new Energy Systems* together with the *Siemens Stiftung* develops a technical concept for implementing the above-mentioned mobility solution into the existing *WE!Hub* at Mbita. This concept should serve as a blue-print for other *WE!Hubs.* In a first step, current load profiles were determined, as the energy demand depends on daily routines of the local community and is strongly linked with the fishing-season at *Lake Victoria*. These load profiles together with the technical specification of the system were used to simulate the annual electricity consumption and production. Subsequently, the potential for integrating further consumers within the context of e-mobility was determined. A best possible distribution of the different consumers throughout the day is of major importance for an economic feasible extension of the investigated *WE!Hub*. Therefore, an appropriate control-strategy will be developed.

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Gender Mainstreaming in Solar Irrigation Projects

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Keywords: gender equity, SPIS, water pumping, gender planning

Traditionally, women are considered as homemaker while men are regarded as the breadwinner of the family. This is a very narrow style of thinking as it neglects the triple role of women: reproductive role, productive role (they are active in informal sector or helping the male members of the family) and community role (voluntary involvement in different women's group to secure community resources such as water, forest etc.)[1]. Understanding these diverse roles is important for gender mainstreaming in solar irrigation systems (SPIS). Traditionally, energy policies have also been gender blind as they assume that male and female have equal access to resources such as land, credit, fertilizers and equipment[2]. This is far from true as different social, cultural and economic conditions result in unequal access to resources between male and female[1].

Gender planning in SPIS systems should follow an interdisciplinary approach as the policies should target inclusiveness both from agriculture and energy side. In terms of agriculture, women are mostly involved in subsistence farming while men traditionally manage large farms or cash crops[3]. Women also own less than 20% of the world's land[4]. This is important while deciding to buy SPIS as women might not have the authority or the resources to afford it. Energy itself is also considered as men' domain and experiences from Pakistan and Nepal show that community mobilization is necessary to demystify it and to involve more women in this sector. These experiences also show that involving women in the energy project not only empower women but also contribute towards the sustainability of the projects. [5].

Gender mainstreaming should be done in all phases of the SPIS projects from planning to operation and maintenance. Example from Practical Action Nepal shows how participatory or gender transformative approach can be applied during the planning phase. Activities such as choosing time that is most suitable for women, appropriate seating arrangement (previously women would sit on the floor and men on the chairs - resulting in already unequal distribution of power), involving women engineers as role models ensure equal participation of women[6]. Examples from ICIMOD Nepal shows how subsidies can be used to increase gender equity during project implementation. ICIMOD provides additional 10% subsidy for SPIS systems if the land is registered in the women's name. This ensures that SPIS systems are not only available to women farmers, but they also have land registered in their name.

These examples show that gender mainstreaming is not a one-time activity but rather has to be planned in every phase. Gender mainstreaming in SPIS projects is also especially tricky as it involves gender sensitivity in both agricultural area and energy area.

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Promoting sustainable communities via appropriately designed and participatory energy access in rural areas of developing countries

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Keywords: Social value of energy; energy-poverty nexus; participatory energy access

With the arrival of modern energy services in rural areas, energy can contribute to improve quality of life and to achieve multiple Sustainable Development Goals (SDGs). For example, electricity can contribute to SDG1 (no poverty) and SDG2 (zero hunger) through its use in agrarian and non-agrarian economic activities that can consequently be performed in less time, with less human or animal force and with less residual losses, increasing productivity and income. Adequate means of cooking can contribute to SDG3 (good health and well-being) by reducing indoor air pollution typically caused by traditional cookstoves based on biomass or three-stone fireplaces. However, the potential benefits of energy oft do not occur automatically as a consequence of access to modern energy services. Moreover, energy can negatively impact rural communities and increase local problems. For example, without adequate institutional governance, energy can increase opportunities for child labor in agrarian and non-agrarian economic activities, leading children to drop out of school. Without adequate awareness and information, energy can be intentionally used to manipulate people for political gains and reinforce inadequate forms of governance, leading to social problems like high inequality and poverty. This study argues that appropriately designed and participatory energy projects can increase the potential benefits of energy access, while minimizing and/or avoiding possible burdens and negative impacts of energy on rural communities. To support this argument, this study presents the results of an applied research project conducted from 2018 to 2019 by a research team from the Arizona State University, USA, and the Karlsruhe Institute of Technology, Germany, in partnership with local organizations from Nepal, Philippines, Uganda and Bolivia (three social enterprises and one non-governmental organization, respectively), supported by the Global Consortium for Sustainability Outcomes. Using a conceptual multi-layer framework for social value creation in a mutual learning process between the research team and local partners, the project aimed to upgrade community-based, off-grid, renewable energy access projects conducted by the local partners in rural areas to create greater social and economic value and advance progress on multiple SDGs. The results indicate that the mutual learning environment allowed the research team to improve the theoretical framework based on evidence and with inputs of local partners, leading to the Ecosystems design approach. This approach helped improve project sustainability by: (a) taking on and achieving more ambitious SDGs, (b) empowering communities to use energy more effectively to create social and economic value, (c) having stronger social designs that synergize with engineering and economics, and (d) reducing financial burdens and negative impacts on project beneficiaries. Finally, the results indicate the importance of a bidirectional process of compilation and transfer between scientific knowledge and practice-based knowledge, to build inclusive and more equitable energy systems for sustainable rural communities.

Results Based Financing to catalyse commercial finance for off-grid solar market development

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Keywords: Results based financing, market development, off-grid solar

Accelerating private sector driven delivery of low carbon energy access in developing countries

While vast numbers of people in developing countries expect to remain off-grid for the coming decades, innovative financing mechanisms are needed to accelerate and scale the dissemination of solutions that bring access to energy to those who need it most, while contributing to climate change mitigation. SNV is among the first organizations world-wide successfully implementing Results Based Financing (RBF) facilities in the energy sector, aimed to overcome market barriers constraining private sector delivery of modern energy services to isolated communities. The key feature of RBF is payment upon delivery, with the private sector expected to take the full risk until the moment of delivery of the contracted results.

Private sector involvement in the sector is essential if we are to reach the Sustainable Development Goal of affordable and clean energy for all. However, companies often face increased risks and challenges to successfully operate their business in developing countries, and particularly to scale their operations into new off-grid markets. By providing a temporary financial incentive to companies to deliver certain energy products and services in off-grid communities, the RBF leverages investments from the private sector to increase access to clean energy in remote areas. As the market develops and economies of scale are achieved, the level of incentive is reduced. RBF provides a flexibility for the private sector to work with different business models, supporting the development of sustainable markets which will continue to grow once the incentives have come to an end.

Supported by different donors and partners including the Energising Development (EnDev) program, DFID, World Bank and AFD, SNV has been closely involved in the design and implementation of RBF facilities in different renewable energy sub-sectors and markets across Africa and Asia. This session will provide an overview of the results and lessons learned so far, with particular emphasis on the case of the RBF Fund for off-grid solar in Tanzania. RBF was used to trigger solar market development in remote, underserved parts of the country. Between 2014 and the end of 2018, the RBF fund in Tanzania has leveraged €13M of private investments which created 1,256 jobs and access to energy products and services for 390,000 people who did not have such access before. The model has been replicated for other energy products and services in Tanzania, and in neighbouring countries. The session will provide an overview of some of these new initiatives and next iterations of RBF designs considering the lessons learned in implementing these facilities so far.