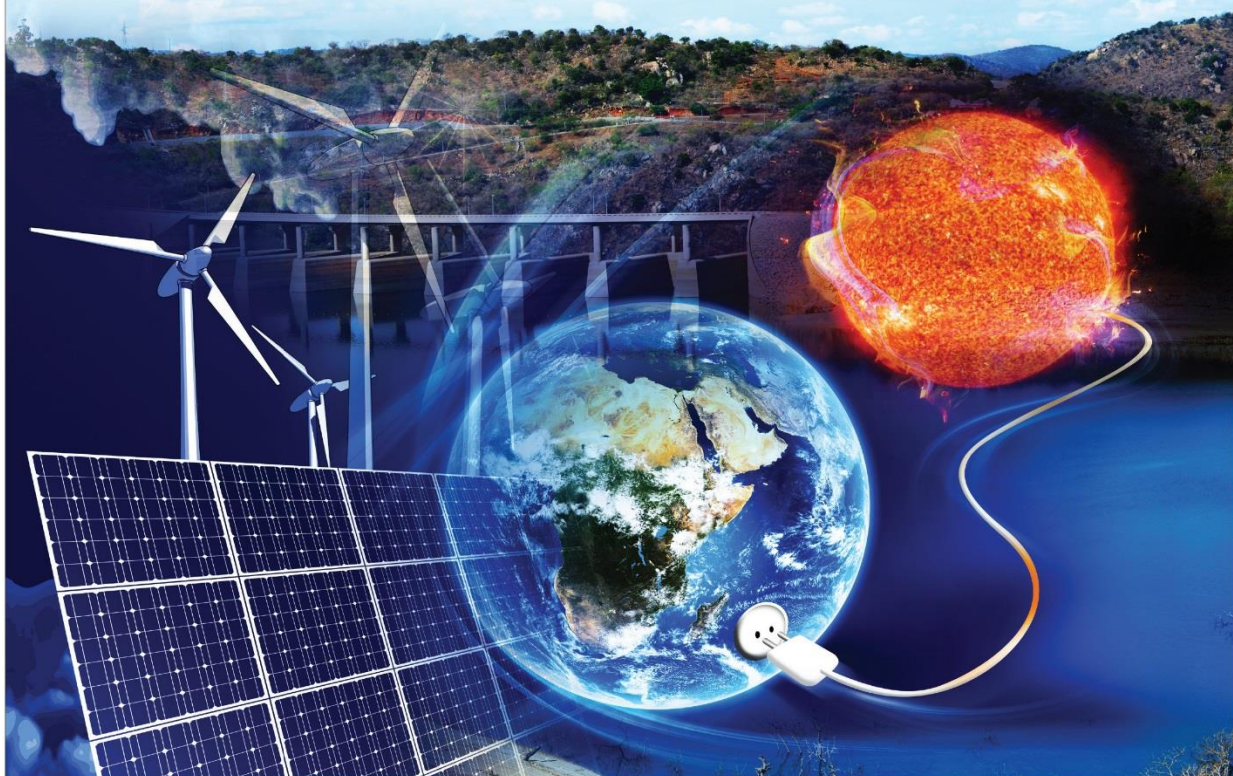


PROCEEDINGS OF THE 3RD INTERNATIONAL CONFERENCE ON INFRASTRUCTURE DEVELOPMENT AND INVESTMENT STRATEGIES FOR AFRICA

DII - 2016

31 August – 2 September, 2016

Livingstone, Zambia



ACHIEVING SOLUTIONS FOR RENEWABLE ENERGY AND SUSTAINABLE DEVELOPMENT

Editors: Dr EM Mwanaumo, Dr I Musonda & Dr F Muleya

Co-editors: Prof M Muya, Dr JN Agumba & Mrs CS Okoro



**Copperbelt
University**



**UNIVERSITY
OF
JOHANNESBURG**

DII – 2016

3rd International Conference on Development and
Investment in Infrastructure Strategies for Africa

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ACHIEVING SOLUTIONS FOR RENEWABLE ENERGY AND SUSTAINABLE
DEVELOPMENT

Editors

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Franco Muleya

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2016

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CONFERENCE SPONSORS



FOREWORD

On behalf of the Organizing Committee, it is my pleasure to welcome you to Livingstone, Zambia, the host city of the 2016 International Conference on Development and Investment in Infrastructure (DII). The DII-2016 conference is part of the DII Conference series on Infrastructure Development and Investment in Africa which aims to provide an international forum for leaders, researchers, practitioners and other stakeholders in infrastructure development to discuss and devise ways of maximizing benefits from infrastructure development in Africa and achieve outputs that will inform policy.

With focus on renewable energy, general infrastructure development and investment in Africa, the 2016 conference, themed “*ACHIEVING SOLUTIONS FOR RENEWABLE ENERGY AND SUSTAINABLE DEVELOPMENT*”, will address a broad range of topics around infrastructure to evaluate and draw lessons on innovations, empowerment, growth and sustainable development.

The broad topics covered by the conference include:

- Infrastructure development strategies for developing countries
- Renewable energy for sustainable growth and development
- Human factors in infrastructure development
- Legal and ethical issues in infrastructure development
- Infrastructure finance, procurement and value engineering
- Sustainable development and growth infrastructure
- Appropriate technology and innovation
- ICT in infrastructure development
- Social infrastructure development in developing countries
- Infrastructure, climate change and pandemics in developing countries

Warm gratitude is extended to the authors who have successfully gone through a two-tier peer review process in order to have their papers accepted and published in this proceeding. The peer review process would have been impossible without the support of the members of the Scientific and Technical review Committees (STC). The organizing committee is thankful for this voluntary service that is so central to the quality of the accepted papers.

Special thank you also goes to all the conference delegates that have travelled from different continents. Thank you for attending the event and please make the most of your time at the conference while enjoying the hospitality of the Zambian people here in Livingstone.



Erastus Mwanaumo

Chair: Technical Programme
DII-2016

ACKNOWLEDGEMENT

The organizing committee of the DII-2016 is grateful to the University of Zambia, Copperbelt University, Zambia, National Council for Construction (NCC), Zambia, University of Johannesburg, South Africa, the Chartered Institute of Building, the Network of Energy Excellence for Development (NEED), the Universal Mining and Chemical Industries Limited, the South African Council for the Project and Construction Management Professions and other South African, African and International universities and Institutions for supporting the conference through their valued contributions.

The contributions and unique support of the International Advisory and Scientific Committees, who worked tirelessly to prepare refereed and edited papers, which produced this published proceedings of the highest standard including satisfying the criteria for subsidy by the South African Department of Higher Education and Training (DHET), is truly treasured. The contributions of Prof Mundia Muya, Dr Trynos Gumbo, Dr Justus Agumba, Dr Ackim Zulu, Prof Didibhuku Thwala, Dr Innocent Musonda, Prof Clinton Aigbavboa, Dr Erastus Mwanaumo, Dr Franco Muleya, Mrs Chioma Okoro, Mr Tresor Mbayahe, Mr Johan de Koker, Ms Chama Mwansa, Dr Brian Mutale and Mr William Nkomo are recognized. The support of Mr Ansary Nazeem and Prof Steve Ekolu is also laudable.

DISCLAIMER

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DECLARATION

All the papers in this volume form the part of the DII conference but were delivered as technical papers under the summit. These papers were not peer-reviewed and thus the detailed process of peer-review did not take place.

CONFERENCE COMMITTEES

Organizing Committee

Zambia

Dr Erastus Mwanaumo (Chair: Technical Programme)

Prof Mundia Muya

Dr Franco Muleya

Dr Ackim Zulu

Ms Chama Mwansa

Mr Brian Mutale

Prof Clive Chirwa

South Africa

Dr Innocent Musonda (Chair: Scientific Programme)

Prof Clinton Aigbavboa

Dr Trynos Gumbo

Dr Justus Agumba

Prof Didibhuku Thwala

Mrs Chioma Okoro

Scientific Committee

This committee ensured that the final papers incorporated the reviewers' comments, were correctly allocated to the appropriate theme and met the requirements set by the organisers in line with international standards for inclusion in the proceedings. They also arranged the papers into their final sequence as captured on the USB memory stick and Table of Contents.

Dr E Mwanaumo, University of Zambia

Dr I Musonda, University of Johannesburg, RSA

Dr F Muleya, Copperbelt University, Zambia

Prof M Muya, University of Zambia

Dr J Agumba, University of Johannesburg, RSA

Technical Review Committee

The technical review committee comprised of experts from the built environment. The committee ensured that the papers were of the highest standard in terms of originality of material; academic rigor; contribution to knowledge; critical current literature review; research methodology and robustness of analysis of findings; empirical research findings; and overall quality and suitability for inclusion in the conference proceedings.

Dr A Zulu, University of Zambia, Zambia
Dr C Trinkl, Technische Hochschule Ingolstadt (THI), Institute of new Energy Systems (InES)
Dr D Mzyece, University of Wolverhampton, UK
Dr E Munshifwa, Copperbelt University, Zambia
Dr L Chipungu, University of Kwazulu-Natal, RSA
Dr M Sumbwanyambe, University of South Africa, RSA
Dr N Chileshe, University of South Australia, Australia
Dr R Ndiokubwayo, Cape Peninsula University of Technology, RSA
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Prof G Ofori, National University of Singapore, Singapore
Prof J Katende, University of Science and Technology, Botswana
Prof J Khatib, University of Wolverhampton, UK
Prof JJ Smallwood, Nelson Mandela University, RSA
Prof KK Shakantu, University of Free State, RSA
Prof Mbaiwa, Okavango Research Institute/Botswana
Prof PD Rwelamila, University of South Africa, RSA
Prof W Zörner, Technische Hochschule Ingolstadt (THI), Institute of new Energy Systems (InES)



The University of Johannesburg (UJ), is the largest, multi-campus, residential university in South Africa. Born from a merger between the former Rand Afrikaans University (RAU), the Technikon Witwatersrand (TWR) and the East Rand campuses of Vista University in 2005, the University of Johannesburg's unique academic architecture reflects a comprehensive range of learning programmes, leading to a variety of qualifications ranging from vocational and traditional academic to professional and postgraduate programmes, across the four campuses, namely: Auckland Park Kingsway, Auckland Park Bunting Road, Doornfontein and Soweto campuses. The campuses vary in size and each has its own character and culture, contributing to the institution's rich diversity.

The University of Johannesburg has benefited from a large pool of researchers bringing together various fields of expertise and research focus areas. The university provides the ideal ground for interdisciplinary research and the university has more than 87 rated researchers. Five of these researchers are A-rated - all of whom are recognized as world leaders in their field. The university is also home to nine research centers.

The University fosters ideas that are rooted in African epistemology, but also addresses the needs of the South African society and the African continent as it is committed to contributing to sustainable growth and development. We continue to build a culture of inclusion, embracing South Africa's rich history, culture, languages, religions, gender, races, social and economic classes. Additionally, the University encourages a culture of service as part of the university student experience and it proudly pursues a four-language policy of English, isiZulu, Afrikaans and Sesotho sa Leboa.

Our staff and students come from over 50 countries in Africa and the world. The university has also built links, partnerships and exchange agreements with leading African and other international institutions that further enrich the academic, social and cultural diversity of campuses. It is also the recipient of the highest levels of external financial support, from donors and partners all over the world. This demonstrates the high esteem in which we are held internationally.

In its mission, UJ commits itself to the following:

- Quality education;
- Leading, challenging, creating and exploring knowledge;
- Supporting access to a wide spectrum of academic, vocational and technological teaching, learning and research;
- Partnerships with our communities; and
- Contributing to national objectives regarding skills development and economic growth.

The values guiding all University activities include:

- Academic distinction;
- Integrity and respect for diversity and human dignity;
- Academic freedom and accountability;
- Individuality and collective effort; and
- Innovation

In giving expression to its vision of being a pre-eminent South African and African University, UJ has set itself ten strategic goals. Its priorities are to:

- Build a reputable brand;
- Promote excellence in teaching and learning;
- Conduct internationally competitive research;
- Be an engaged university;
- Maximize its intellectual capital;
- Ensure institutional efficiency and effectiveness;
- Cultivate a culture of transformation;
- Offer the preferred student experience;
- Secure and grow competitive resourcing; and
- Focus on the Gauteng city regions.



The Copperbelt University

History

With its motto “Knowledge and Service”, the Copperbelt University (CBU) was established in 1987 as part of the University of Zambia. It was initially intended to be located in Ndola, about 50km South East of Kitwe, as UNZANDO (University of Zambia in Ndola). But since the University of Zambia (UNZA) had no infrastructure in Ndola at the time, UNZANDO was allowed to operate in Kitwe using the Zambia Institute of Technology (ZIT) infrastructure. ZIT was integrated into Copperbelt University in 1989, two years after the university was established. Until recently (when many public and private universities are being established), the Copperbelt University was the only other university in the country after the University of Zambia. Currently, the university has eight academic schools – Schools of the Built Environment, Engineering, Medicine, Graduate Studies, Business, Mines and Mineral Sciences, and the School of Natural Resources. In addition, the University offers distance education through its Directorate of Distance Education and Open Learning. The Dag Hammarskjold Institute for Peace Studies is accommodated at Copperbelt University.

The School of Built Environment

The School of the Built Environment (SBE) (formerly School of Environmental Studies) was established in 1981 under ZIT when the School admitted its first students. The School remained temporarily situated at ZIT until 1989. The School of the Built Environment (SBE), therefore, increased its scope by taking on the ZIT Diploma courses in Architecture, Quantity Surveying, Land Surveying and Town & Country Planning, and Advanced Technician course in Construction. The University began to offer these programmes at degree level. Currently, the School consists of four departments, namely: Architecture, Construction Economics and Management (CEM), Real Estate Studies (RES, formerly Land Economy), and Urban & Regional Planning (URP). In addition, the school also offers a Master of Science programme in Project Management. The School also runs a Project and Consultancy Section called the Practice Office, which is responsible for undertaking consultancy services in various fields of the built environment. Currently, there are 5 undergraduate and 1 masters’ degree programmes offered in the school. These are BSc. in Quantity Surveying, and BSc. in Construction Management (both offered by the CEM Department); BSc. in Real Estate Studies (offered by the RES Department); BSc. in Urban & Regional Planning (offered by the URP Department); Bachelor of Architecture (BArch, offered by the Architecture Department); and the MSc. in Project Management (offered by the School of Graduate Studies).

After successful completion of their degree programmes, our students join both public and private sector reputable organizations within and outside the country where they work as Architects, Design Consultants, Construction Managers, Valuers, Planners, Project Managers, Quantity Surveyors, Investment Bankers and many more. Other than the masters programme, which takes up to two years to complete, all our undergraduate programmes should take five years to complete. Our students come

from within and outside Zambia. In terms of staffing, it is the policy of the University that it recruits highly qualified personnel. For this reason, the university has put in place a policy where the minimum qualification of a lecturer is not only a masters' degree but also that the masters' degree must be in the same discipline as the lecturer's first degree. In addition to this profile, the SBE has a very ambitious programme where it intends to expand the school by introducing more programmes like the MSc. Degree in Land Management. This will help in meeting the ever increasing demand for qualified professionals within and outside the SADC region. More information on CBU in general and SBE in particular, can be found on our website at www.cbu.edu.zm.



THE UNIVERSITY OF ZAMBIA

The School of Engineering, University of Zambia

Introduction

University of Zambia opened its doors in 1966, two years after Zambia attained its independence. The main purpose was to produce human resources (graduates) for the government and industry in Zambia. From the first intake of students of 300, the population has grown to the current population of 21,700. The School of Engineering located at the main campus of the University of Zambia in Lusaka is one of the nine schools in the university. Over the years, the school has responded to various national challenges through teaching, research, training, consultancy and public service. The School of Engineering, now comprising the Departments of Agricultural Engineering, Civil & Environmental Engineering, Electrical and Electronic Engineering, Geomatics Engineering and Mechanical Engineering was established on 1st May 1969.

The school has a student population that is in excess of 450 undergraduate and 90 postgraduate students across all the departments. There are currently 40 academic members of staff in its five departments. The school is realigning itself to become a trainer of trainers by increasing its capacity in training at postgraduate level. The postgraduate programmes aim at training engineers with advanced and in depth knowledge in specialized fields.

The number of postgraduate programs remained small for a long period of time until the year 2010 when it became clear that there was a serious gap in trained manpower in the energy sector. To address this gap, the University of Zambia, School of Engineering with the financial support from NUFFIC, developed a master's degree program in Renewable Energy. This programme is hosted by the School of Engineering. From this experience, the School identified many gaps in engineering management fields, the ICT sector, and project management area and developed a number of other programs in electronics, construction and engineering management. The aim was to elevate the caliber of engineers in the country to improve the management of engineering firms in line with the new technologies.

Postgraduate Programmes in the School

PhD research programmes

PhD research programmes offer a vast range of opportunities to students who relish the chance to undertake a research project with clear intellectual, scientific, industrial or commercial relevance and challenge. Currently these programmes are being offered in the Departments of Civil & Environmental Engineering and Mechanical Engineering. The School also undertakes interdisciplinary research in conjunction with other institutions.

MSc programmes

The following is the list of programmes offered at MSc level:

- Master of Engineering Research Programme;
- Master of Engineering in Agricultural Engineering;
- Master of Engineering in Environmental Engineering;
- Master of Engineering in Structural Engineering;
- Master of Engineering in Electrical Power Systems;
- Master of Engineering in Production Engineering and Management;
- Master of Engineering in Thermo-fluids Engineering;
- Master of Engineering in Renewable Energy Engineering;
- Master of Engineering in Project Management;
- Master of Engineering in Construction Management;
- Master of Engineering in Engineering Management;
- Master of Engineering in Geo-Informatics and Geodesy;
- Master of Engineering in Telecommunications Systems;
- Master of Engineering in Information and Communication Technology;
- Master of Engineering in Information and Communication Technology Security;
- Master of Engineering in Information and Communication Technology Policy and Management;
- Master of Engineering in Computer Communications; and
- Master of Engineering in Wireless Communications.

With these new strides, the university answers the call from society, which requires a pool of well-trained engineers meeting the challenges of operating in the developing world while meeting the challenges of both the developing and developed economies.

CONFERENCE PROGRAMME

WEDNESDAY, AUGUST 31, 2016			
14:30-16:50	Workshop: Postgraduate research		
17:00-19:00	Conference Registration		
	Networking opportunity & welcome cocktail		
THURSDAY, SEPTEMBER 1, 2016			
07:30-08:30	Registration		
	Welcome ceremony & Keynotes Chair: Dr E. Mwanaumo– Assistant Dean Post Graduate , School of Engineering – UNZA		
08:30-08:50	Welcome addresses- <i>Dr Innocent Musonda & Dr Erastus Mwanaumo</i>		
08:50-09:30	High shares of renewable energy and renewable fuels for mobility in the energy system – concepts and critics taking the example of the German “Energiewende” (energy turnaround) - <i>Dr LudgerEltrop, IER, Universität Stuttgart</i>		
09:30-10:10	Alternative methods of creation of an optimal electricity supply-demand structure to serve Zambia - <i>Dr Simon Tembo, University of Zambia</i>		
10:10-10:50	Why are renewables so successful in Germany? - <i>Prof. Dr.-Ing. Wilfried Zörner, Technische Hochschule Ingolstadt, Institute of new Energy Systems</i>		
10:50-11:10	Tea break/Networking		
	Technical Sessions		
	Breakaway Session 1:	Breakaway Session 2:	Breakaway Session 3:
	Theme: Renewable Energy Infrastructure Development Session chair: Dr C. Kaliba	Theme: Integrative Infrastructure Planning and Management Session chair: Dr B. Mwiya	Theme: ICT and Skills Transfer in Infrastructure Development Session chair: Dr E. Munshifwa
11:10-11:30	Evaluation of the Chitungwiza, Firle and Crow borough municipal sewage plants’ potential to produce biogas from municipal sewage sludge for electricity generation: Case Study Zimbabwe - Manyuchi, M. <i>et al</i>	Critical success factors for managing infrastructure projects in Africa: A critical review and lesson learned – Chileshe, N. <i>et al.</i>	Knowledge exchange in construction practice: Exploring the impact of embedded BIM process standards – Maradza, E.
11:30-11:50	Innovative municipal solid waste management in the city of Johannesburg: Towards sustainable green landfill gas to electricity infrastructure – Gumbo, T. <i>et al.</i>	Establishing the relationship of cost changes to construction work groups and the estimated construction cost to improve overall project control– Oliphant, D. <i>et al.</i>	Challenges faced by construction companies in retention of workers in South Africa: A literature review - Nkomo M. W. <i>et al</i>
11:50-12:10	Turning to smart grid in Zambia - Namukolo, S. <i>et al.</i>	Optimisation of tyre traction force in wheeled construction related vehicles traversing in off-road deformable terrain – Muleya, F. <i>et al.</i>	Equipping 21st century construction graduates: a review of key skills in fostering infrastructural development – Aliu, J. <i>et al.</i>
12:10-12:30	Evaluation of infrastructure development of roadway new technologies for renewable energy generation: Lessons learnt – Oladele, A. S.	Modelling uncertainty of cost and time in infrastructure projects – Moghayedi, A. <i>et al.</i>	Sustenance of construction skills – A case for Zambia – Nondo, C. M.
12:30-12:50	Strategic Direction to Sustainable Electricity Generation in Zambia - A Critical Comparison of Electricity Generation Options – Tembo, S. <i>et al.</i>	An appraisal of critical risk factors in construction projects in South Africa: Perspective of contractors – Renault, B. Y. <i>et al.</i>	The Utility of the ‘Step-In’ Clause in the South African Prison Public Private Partnerships – Khatleli N.
12:50-13:50	Lunch Break		
	RENEWABLE ENERGY TECHNOLOGIES SUMMIT – NEED PROJECT Chair: Mr D. M. Ngendo / Dr Ackim Zulu		
14:00-14:10	Introduction - Dr Ackim Zulu (UNZA) & Prof WilfriedZörner (THI)		
14:10-14:30	Keynote: Status of energy supply in Zambia: Perspectives / way forward, integration of renewables, legislative framework and regulations to increase renewable energy in the national energy mix - <i>Eng. Geoffrey Musonda - CEO Rural Electrification Authority (REA)</i>		
14:30-15:10	Research Requirements in Renewable Energy Technologies for Southern Africa - Dr Ackim Zulu (UNZA)		

15:10-15:50	Dual Studies – An Alternative Pedagogy for RETs in Southern Africa - <i>Mr Andrew Zulu (NUST)</i>		
15:50-16:30	Development and Harmonization of Renewable Energy Technology (RET) standards through the Southern African Development Community Cooperation in Standardization (SADCSTAN) platform - Prof James Katende (BIUST)		
16:30-17:00	Tea Break		
17:00-17:40	Perceptions of tourism operators towards the use of RETs in the Okavango Delta, Botswana m- Prof Joseph E. Mbaiwa, ORI		
17:40-18:20	Sustainable Development of Renewable Energy Mini-grids: A case of Gobabis in Namibia - Dr Paul Chisale, NUST		
18:20-18:30	Closing remarks Dr Ackim Zulu (UNZA & Prof Wilfried Zörner (THI)		
19:00-22:30	Gala Dinner		
FRIDAY, SEPTEMBER 2, 2016			
	Keynotes Chair: Dr. J. Agumba		
08:30-09:00	Production of Rebars - Requirements, processes and benefits – <i>Dr Julius Kaoma, Universal Mining and Chemical Industries, Zambia</i>		
09:00-09:40	Project Finance for the Construction Sector in Africa: Challenges and Prospects- <i>Dr Lubinda Haabazoka, Copperbelt University, Zambia</i>		
09:40-10:20	The importance of water resource management and environmental protection in the development of economic infrastructure – <i>Eng. Christopher Chisense, Zambezi River Authority, Zimbabwe & Zambia</i>		
10:20-10:40	Tea break		
	Technical sessions		
	Breakaway Session 4:	Breakaway Session 5:	Breakaway Session 6:
	Theme: Infrastructure Leadership and Governance Session chair: Dr. N. Chileshe	Theme: Sustainability Session chair: Dr T Gumbo	Theme: Health and Safety in Infrastructure Development Session chair: Dr V. Samwinga
10:40-11:00	An evaluation of political risks affecting international construction projects in Namibia – Muchenga, I. <i>et al.</i>	Failure of small and medium contracting firms in Gauteng province, South Africa – Oke, A. <i>et al.</i>	An evaluation of the attitude and behaviour of casual workers towards health and safety on construction sites on Zambian construction industry – Mutwale, J <i>et al.</i>
11:00-11:20	Compliance of public sector targeted procurement strategies to CIDB specification - Adediran, A. <i>et al.</i>	Adoption of best value selection criteria in the Zambian road sector – Mwiya, B. <i>et al.</i>	Identifying health risks related to construction of water supply infrastructure: Case of Lusaka water, supply, sanitation and drainage project - Mwanaumo, E. <i>et al.</i>
11:20-11:40	Stakeholder participation in monitoring and evaluation of construction projects in Ghana – Callistus, T. <i>et al.</i>	Exploring factors that influence firm’s growth among small and medium-sized construction firms in Ghana – Arthur-Aidoo, B. M. <i>et al.</i>	The influence of workers ‘attributes on organisational safety performance – Lusenga, E. <i>et al.</i>
11:40-12:00	Exploring Gilbert’s behavioural engineering model in enhancing risk allocation in the construction industry – Tembo, C. K. <i>et al.</i>	Sustainable water provision for the urban poor: Rights-based or commodity-based Approach? – Kaunda, B. S. <i>et al.</i>	The impact of environmental thermal changes on construction health and safety (H&S) in Zimbabwe – Chigara, B. <i>et al.</i>
12:00-12:20	Performance of construction projects in South Africa: Perception of consultants and contractors - Aigbavboa, C. <i>et al.</i>	Evaluating the use of PPPs in delivering sustainable building projects in Zimbabwe – Mawondo-Dhliwayo, R. A. <i>et al.</i>	Utilisation of materials safety data sheet on Zambian construction worksites- Mwanaumo, E. <i>et al.</i>
12:20-12:40	Investigating factors leading to project abandonment in the ZCI: A case of the public sector - Chiponde, D. B. <i>et al.</i>	Impact of involvement of foreign companies on Zimbabwe’s public sector projects –Mukawa, M. <i>et al.</i>	Conceptualized integrated health and safety compliance model for contractors in Ghana- Mustapha, Z. <i>et al.</i>
12:40-13:40	Lunch Break		
	Keynotes		

	Chair: Dr. F. Muleya	
13:40 -14:10	TBA - <i>Eng. Wallace Mumba. National Road Fund Agency, Zambia</i>	
14:10–14:40	Practical ways of promoting joint ventures of foreign and local contractors within the SADC region – <i>Eng. Charles Mushota, National Council for Construction, Zambia</i>	
	Breakaway Session 7:	Breakaway Session 8:
	Theme: Social Infrastructure and Sustainability Session chair: Prof C. Aigbavboa	Theme: Integrated Infrastructure Investment, Procurement and Finance Session chair: Dr M Manyuchi
14:40-15:00	An evaluation of the development of renewable energy sources in South Africa – Daw, D.	Assessment of credit accessibility to construction SMEs in the South African construction industry using binary logistic regression- Balogun, L. <i>et al.</i>
15:00-15:20	Developing alternative roof tiles from plastic waste and copper tailings - Siluonde, H. <i>et al.</i>	Sovereign bonds and infrastructure development in Africa: the case of Zambian road infrastructure - Munshifwa, E.
15:20-15:40	Policy and legal imperatives for delivering affordable housing in Zambia: Post 2000 – New Millennium – Phiri, D. A.	Comparison of the clients, consultant and contractors perspectives of pre-tender unit cost factors in Zambia – Chipulu C. <i>et al.</i>
15:40-16:00	The effect of Johannesburg inner-city regeneration of the resident communities - Khatleli N. <i>et al.</i>	Critical considerations in transport performance forecasting: A literature review – Okoro, C. S. <i>et al.</i>
16:00-16:20	Key factors for the development of sustainable stakeholder management framework for construction projects in Ghana – Eyiah-Botwe, E. <i>et al.</i>	Development of a conceptual main contractor-subcontractor partnering model -Mudzvokorwa, T. <i>et al.</i>
16:20-16:50	Conference End and Closing: Q&A with Keynote Speakers; Closing Remarks - Prof Wellington Thwala- (UJ)	
16:50	Sunset Cruise on the Mighty Zambezi River – (Optional event)	

KEYNOTE SPEAKERS' PROFILES

The Infrastructure Investment and Development (DII) conference is an international conference which provides a forum for discourse on the status quo regarding Africa's massive shortfall in infrastructure development and investment that limits its productive capacity and global competitive advantage. Inaugurated in 2014 in Livingstone, Zambia, the conference has been jointly hosted by the University of Johannesburg, the University of Zambia, Copperbelt University, National Council for Construction of Zambia, the Construction Industry Development Board of South Africa, and the Chartered Institute of Building of United Kingdom the Africa Region, and has recently been supported by the Network of Energy Excellence for Development (NEED), a project funded by the European Union (EU) and implemented by the African, Caribbean and Pacific Group of States (ACP). Themed, "*ACHIEVING SOLUTIONS FOR RENEWABLE ENERGY AND SUSTAINABLE DEVELOPMENT*", the 2016 conference will focus on renewable energy, general infrastructure development and investment in Africa, addressing a broad range of topics around infrastructure investment, development and sustainability. The conference is a great platform for international delegates including Built Environment professionals, researchers, academics and post-graduate students who are passionate about eliciting solutions to the challenges faced in infrastructure provision and sustainability. The conference further offers platform for brainstorming and probing into strategies to realise Africa's vision in securing the future and attaining full potentials in infrastructure development and investment. Confirmed keynote speakers include:

Prof. Dr.-Ing. Wilfried ZÖRNER

Prof. Dr.-Ing. Wilfried Zörner is Professor for Product Development and Design (since 1998), currently heads the Institute of new Energy Systems (InES), and is member of the research council at Technische Hochschule Ingolstadt, Germany. He lectures at the same institution presenting Renewable Energies, Solar Energy Engineering, Product Design, Design Elements, Pneumatics and Cost Management. He was previously Head of Research at the Research Institute for Renewable Energies, Neuburg, Germany. He has conducted various renewable energy research projects including '*Optimisation of biogas production with regard to plant design and electricity grid interaction*', '*System analysis and development of optimal system design of thermosyphon solar water heaters*', '*Application of solar-thermal systems for process heat in industrial use*' and '*Feasibility analyses on alternative design solutions and polymeric materials for solar-thermal collectors considering production process automation*'. Prof Zörner holds a PhD (Dr.-Ing.) in Solar Energy Systems and Dipl.-Ing. in Mechanical Engineering, both from Technical University of Munich, Germany. He is a member of Task 49 (Solar Heat Integration in Industrial Processes) and Task 39 (Polymeric Materials for Solar Thermal Applications) within the Solar Heating and Cooling Programme of the *International Energy Agency*, member of the advisory committee of the German Solar Thermal Technology Platform (DSTTP), member of the scientific committee of Euro sun 2010 conference (Graz, Austria) and consults with the industry in the field of sustainable energy.



In his speech, Prof ZÖRNER wants to answer the question ‘*Why are renewables so successful in Germany?*’ In doing so, he will show the status of renewables in Germany and then concentrate on electricity generation aspects. He will explain what happened in Germany to boost renewable electricity generation and put a focus on energy legislation. Prof ZÖRNER hopes to provide advice (at high level) on the approach developing nations could adopt.

Eng. Geoffrey MUSONDA



Eng. Geoffrey Musonda has extensive practical experience in project management of power development and policy formulation. Eng. Musonda has worked with the private sector and in international organisations such as the United Nations Industrial Development Organization (UNIDO). He is currently the Chief Executive Officer (CEO) for the Rural Electrification Authority (REA) and is a former Assistant Director at the Ministry of Mines, Energy and Water Development (Department of Energy). Eng. Musonda holds a Master’s Degree in Maintenance Engineering from Augsburg University of Applied Sciences, Germany and a Bachelor’s Degree in Mechanical Engineering from the University of Zambia.

Eng. Musonda will speak on the “*Status of energy supply in Zambia, perspectives/way forward, integration of renewables, legislative framework and regulations to increase renewable energy in the national energy mix*”.



Eng. Christopher CHISENSE

Eng. Christopher Chisense holds a Master degree in Environmental Engineering from University of Nottingham, in United Kingdom, and Bachelors of Engineering in Mining Engineering from University of Zambia. He is a registered Engineer with EngRB, Professional Member of Engineering Institute of Zambia and a Professional Impact Assessment Member. He is currently a Director -Water Resources & Environmental Management, at the Zambezi River Authority. Eng. Chisense will address delegates on “*The importance of water resource management and environmental protection in the development of economic infrastructure*”. Development of small and large dams is key for sustainable water resources management for economic and social development in a world where population increase and the development agenda are leading to increased demand for water and energy and treating available limited water resources and environmental protection as well. Countries are increasingly planning to use water infrastructure to systematically and sustainably harness the available water resources to meet the demands of society without causing the limited resource neither to run out nor to cause threats to existing ecosystems and the environment. The International Commission on Large Dams (ICOLD) during its 24th Congress in Kyoto, Japan on 5th June 2012 made a World Declaration on Water Storage which stated that “Humanity is facing a more severe water situation than it has ever faced in the past” and calls for “Joint efforts to develop water storage infrastructure in a sustainable way.” If society is to

harness water resources sustainably and with environmental protection in mind, this declaration points to key strategy that is implementable for sustainable water resources management especially in the wake of climate change.

Dr. Ludger ELTROP



Dr Ludger Eltrop is the Head of Department in System Analysis and Renewable Energies at the Institute for Energy Economics and Rational use of Energy - University of Stuttgart, Germany. He lectures in renewable energy technologies, bioenergy and RE systems. Dr Eltrop has conducted research on acid rain impact on sugar maple, renewable energy and integration into energy systems, research and development projects in biomass and solar energy and systems integration of renewable energy technologies international in Asia, Africa and South America. He has been Research Assistant in Fungal Microbiology and Research Assistant in Plant Physiology at University of Toronto. Dr Ludger Eltrop holds a PhD in agricultural and environmental sciences, from Universität Hohenheim, German, a post-diploma research on nutrient cycles in mycorrhizal fungi and a Diploma in Biology, allgemein, Rheinische Friedrich-Wilhelms-Universität Bonn.

Dr Ludger Eltrop will cover *“Mobility and use of alternative fuels and biogenic gases from biowaste and landfill”* and will report from some *experiences in Germany on penetration and high shares of renewable energy in the energy system, solar and wind energy*. Dr Eltrop’s presentation will *address the systems integration aspect“*.

Dr. Lubinda HAABAZOKA



Dr. Lubinda Haabazoka is a Senior Lecturer in Economics, Banking and Finance in the School of Business. He is currently Head of the Accounting and Finance Department. He holds a Doctor of Philosophy degree in economics with a focus on Banking, Master of Science degree in Finance and Credit with a specialization in Banking from Rostov State Economics University (Russia).

Dr Haabazoka has worked at the Copperbelt University since 2010 and also serves as northern region Economics Association Zambia Chairperson. As Senior Lecturer at the Copperbelt University, Dr. Haabazoka has conducted several research projects, among which are a study on Capital Market developments in Zambia, the National Economic Advisory Council commissioned study on youth employment creation in Zambia (with other researchers) and the National Economic Advisory Council study on Railway Industry Developments in Zambia. In the last four years, he has conducted research on employment creation, Effects of Fuel Price Subsidy Removal in Zambia, Role of Banking Sector in Economic Development and Diversifying the Copperbelt’s economy. Dr Haabazoka is also author of four academic books and more than twelve academic research papers. He has presented a number of academic papers at international conferences in Europe, Asia and Africa.

Dr Haabazoka will endeavour to answer the questions: *Is Zambia and Africa ready for one sided DFI? Or should Zambia and Africa push for a more balanced /equitable sharing of investment? Does Africa have choice in the matter?*

Dr. Simon TEMBO



Dr. Simon Tembo has over 20 years of experience in the ICT /Telecommunications sector with expertise on equipment Conformance and Interoperability (C&I) as a practitioner, academic and researcher. His expertise in strategic planning and operation for the ICT/Telecom operators; developing policy and regulation; and network planning and development has enabled him to develop curriculum for the Master and Bachelor of Engineering degree programmes in ICT/Telecom at the University of Zambia. He has also developed a diploma programme curriculum in Legal and Industrial Metrology. Dr. Tembo has published widely in both Journal and conference publications on human capacity development. He is a former CEO / Managing Director of Zambia Telecommunications Company Limited (ZAMTEL), Assistant Dean Postgraduate in the School of Engineering at the University of Zambia, and he is currently serving as the Head of Department for Electrical and Electronic Engineering Department in the School of Engineering at the University of Zambia. Dr. Tembo is a member of the Energy Regulation Board Grid Code Technical Committee, where he serves as a Vice Chairman. He holds a Dr. Eng. Degree in Electrical, Electronic and Computer Systems Engineering from Akita University in Japan, a Master of Engineering. Degree in Information and Network Science from University of Electro-Communications in Japan, a Bachelor of Engineering Degree in Electrical and Electronics Engineering from the University of Zambia and a Registered Practicing Engineer with Engineers Registration Board of Zambia.

Dr Simon Tembo will address the delegates on *New Strategic Direction to Generate Electricity in Zambia – the Smart Grid Power Generation in the 21st Century*. The 2015/2016 drought which the country experienced has revealed the risks, uncertainties and consequences involved in dependence on the hydropower generation. This has led to electricity load shedding throughout the country thereby affecting every sector of the country's social-economy. The impact of load shedding has been increasingly severe and diverse on all spheres of the country's economy. There is an urgent need for Zambia to switch over from conventional hydropower generation to create a diverse electricity generation (called source mix) by promoting the use of other energy technologies that are sustainable and can meet the present and projected country's electricity demand. His presentation will share the experience and methods other countries have adopted to create an optimal electricity supply-demand structure to serve the nation.

Eng Charles MUSHOTA



Eng. Charles Mushota is the Executive Director of Zambia's National Council for Construction. He is a Civil Engineer by profession and holds a Master of Science in Infrastructure Planning, a Bachelors of Engineering in Civil Engineering and a Post-Graduate certificate in International Construction Management. He has served the built environment in many capacities including being the Director and Chief Officer at the Road Development Agency, Deputy Director (Standards) at the Zambia National Tender Board and an Executive Director at Estal Pride Limited.

Other previous engagements include being contracted by the Uganda National Road Authority (UNRA) to carry out an evaluation of priority road tenders in 2011, a Lecturer at University of Zambia, a Consultant to the Technical Education, Vocational and Entrepreneurship Training Authority (TEVETA) and also an imprest Accounting Officer for the European Development Fund. Eng. Mushota serves on many committees such as the Zambia Certified Accountant's Tender Committee, Food Reserve Agency Tender Committee and National Water and Sanitation Council Tender Committee. He is a deputy task manager for the Public Expenditure Management and Financial Accountability Programme (PEMFA) at the Ministry of Finance and National Planning, a Commissioner at the Energy Regulation Board Commission of Inquiry and a member of the National Pensions Scheme Authority.

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KEYNOTE ADDRESSES

High Shares of Renewable Energy and Renewable Fuels for Mobility in the Energy System – Concepts and Critics taking the example of the German “Energiewende” (Energy Turnaround)

Dr. Ludger Eltrop

Abstract

The energy world has changed drastically, at the latest after the Fukushima nuclear accident in March 2011. Many countries of the world have focused their energy policy towards renewable energy and exploiting their own regional energy resources. The challenges for an energy system with high shares of renewables are nevertheless high. To meet the variable energy demand, the fluctuating solar and wind energy needs to be compensated by other flexible energies, particularly biomass and geothermal. Other technologies and e.g. storage add on to what is known as flexibility options and a merit order of flexibility. The potentials of renewable energy are high, but technologies need to be organized in a smart way. Recent developments show a trend towards “sector coupling” - the interconnection and merging of electricity generation, thermal energy and mobility. High amounts of renewable electricity can be converted to gaseous fuels (e.g. hydrogen, methane) or heat at times when electricity demand is low. These technologies, widely known as Power-to-X (P2X), play an important role in balancing an energy system with high shares of renewable energy. The mobility sector plays a particular role in P2X concepts. Excess renewable electricity can be converted to gaseous fuels (hydrogen, methane) or used directly in electric vehicles. Renewable fuels are widely used in various parts of the world and are now successively growing together with the (renewable) energy sector. In the presentation, the use of renewable fuels and the interconnection with the power sector are described and demonstrated, taking the example of Germany and other European countries, where high shares of renewables are an explicit objective of energy policy.

Keywords: renewables, flexible energies, sector coupling

New Strategic Direction to Generate Electricity in Zambia: The Smart Grid Power Generation in the 21st Century

Dr. Simon Tembo

Abstract

The 2015/2016 drought which the country experienced has revealed the risks, uncertainties and consequences involved in dependence on the hydropower generation. This has led to electricity load shedding throughout the country thereby affecting every sector of the country's social-economy. The impact of load shedding has been increasingly severe and diverse on all spheres of the country's economy. There is an urgent need for Zambia to switch over from conventional hydropower generation to create a diverse electricity generation (called source mix) by promoting the use of other energy technologies that are sustainable and can meet the present and projected country's electricity demand.

This presentation shares the experiences and methods other countries have adopted to create an optimal electricity supply-demand structure to serve the energy needs of the nation.

Keywords: electricity generation, smart grid, Zambia

Why are Renewables so Successful in Germany?

Prof. Dr.-Ing. Wilfried Zörner

Abstract

This presentation enlightens on why renewables are successful in Germany. The status of renewables in Germany is shown, with a focus on electricity generation aspects. The factors and occurrences which contributed to boosting renewable electricity generation, with a focus on energy legislation are also addressed. In addition, the presentation provides advice (at high level) on the approach which developing nations could adopt.

Keywords: energy, renewables, success factors, sustainability

Project Finance for the Construction Sector in Africa: Challenges and Prospects

Dr. Lubinda Haabazoka

Abstract

The construction sector remains one of the most important economic sectors of any country's economy. A well-developed construction sector is a prerequisite to enhanced infrastructure development which is cardinal to a country's economic development. One of the factors that enhance construction sector growth is finance. Unfortunately, Africa still is unable to attract large investments into its construction sector as compared to other continents because investors view the continent mostly as a source of cheap mineral resources.

The main aim of this paper is to outline the role of project finance in enhancing construction sector growth in Africa. The paper also aims to outline the size of Africa's construction industry, major sources of project funding and also study the challenges and prospects for the sector.

The paper contains 6 sections: Section one is the introduction; Section two gives an overview of Africa's construction sector; Section three outlines the main sources of construction sector project funding in Africa; Section four presents an overview of Zambia's construction sector and its funding structure; Sections five discusses the challenges facing project finance in Africa's construction sector; and section six offers prospects for construction sector growth in Africa.

In general, the presentation attempts to answer the following: *Is Zambia and Africa ready for one sided DFI? Or should Zambia and Africa push for a more balanced /equitable sharing of investment? Does Africa have choice in the matter?*

Keywords: Africa, construction sector, project finance, public private partnerships

Production of “UMZ” High Quality Steel Rebars: Requirements, Processes and Benefits

Dr Julius Kaoma

Abstract

Universal Mining & Chemical Industries Ltd - Kafue Steel Plant manufactures high quality rebars under the “UMZ” trade name. This brief presentation will enlighten on the manufacturing of these high quality rebars. The following are highlighted:

- i) the consumers’ requirements with respect to the properties of rebars;
- ii) different processes for the production of rebars under which the process of “UMZ” high quality rebars will be described; and
- iii) the benefits that accrue when the UMZ rebars vis -a-vis their properties when used.

Keywords: high quality production, steel rebars

The Importance of Water Resource Management and Environmental Protection in the Development of Economic Infrastructure

Eng. Christopher Chisense

Abstract

Development of small and large dams is key for sustainable water resources management for economic and social development in a world where population increase and the development agenda are leading to increased demand for water and energy and treating available limited water resources and environmental protection as well. Countries are increasingly planning to use water infrastructure to systematically and sustainably harness the available water resources to meet the demands of society without causing the limited resource neither to run out nor to cause threats to existing ecosystems and the environment. The International Commission on Large Dams (ICOLD) during its 24th Congress in Kyoto, Japan on 5th June 2012 made a World Declaration on Water Storage which stated that “Humanity is facing a more severe water situation than it has ever faced in the past” and calls for “Joint efforts to develop water storage infrastructure in a sustainable way.” If society is to harness water resources sustainably and with environmental protection in mind, this declaration points to key strategy that is implementable for sustainable water resources management especially in the wake of climate change.

Keywords: economic development, environmental protection, water resource management

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RENEWABLE ENERGY TECHNOLOGIES SUMMIT (RETS) PAPERS

Research Requirements in Renewable Energy Technologies for Southern Africa

Ackim Zulu¹, Mwansa Kaoma², Mundia Muya³, Shadreck Mpanga⁴, Donat Ngendo⁵

Abstract

This paper presents the outcome of an assessment of the research needs in Renewable Energy Technologies (RETs) as applied to the Southern Africa region. The Southern African region is endowed with extensive renewable energy (RE) resources but is somewhat retarded in the development and assimilation of RETs which could increase the human development index of the countries in the region and help preserve the environment by avoidance of technologies that exploit polluting resources. This work has the premise that RETs in the region need to be developed and starts with identification of the immediate research needs. The approach to identifying the research needs was based on discussions held with targeted stakeholders, through innovative arrangements of focus groups, with the results of the discussions assessed for common elements. The investigation revealed four main areas that had common ground and had popular appeal, namely solar energy, bioenergy, control aspects and cross-cutting issues. It is believed that the results of this work can form a basis for creating well-directed development plans that systematically move the region in a common development direction.

Keywords: academic research, development, environment, renewable energy technologies, strategic planning

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1. Introduction

This paper discusses the research requirements for renewable energy technologies (RETs) in Southern Africa (SA). The discourse builds on the work which identified the existing situation for RET in the region (Kaoma *et al*, 2015). The SA region is geographically identified as the African region generally falling south of the equator (New World Encyclopedia, 2008) and is defined by the economical, social and political grouping inscribed wholly by Southern African Development Community (SADC) and partly by Common Market for Eastern and Southern Africa (COMESA). The region under discussion has uniformity in climate, peoples, and social arrangements. The economic development and economical aspirations are also largely at the same level, except for the Republic of South Africa which is significantly more advanced than the rest of the region.

1.1 State of renewable technologies in SA

In SA, there are five dominant renewable energy (RE) resources with their associated technologies, identified as solar, bio-energy, hydro, wind and geothermal, this order also representing the ranking in importance and availability (Kaoma *et al*, 2015).

A number of notable plans for exploiting the RE resources in SA have been catalogued but the impact of these plans is merely of a token stature when considered against the size of the population represented in the scope. Further insight shows that the RETs in the region are not well-developed and the RE resources are practically untapped. However, there appears now to be some form of concerted effort to create plans that would systematically exploit the resources and eventually lead to improvement in the livelihood of the SA population.

The revelation of the gulf between the potential and the under-development of the resources that emerge from ponderings on the state of RET in the region sets a persistently paradoxical outcome. A number of well-understood barriers have been advanced for this situation (Karekezi and Kithyoma, 2003), and the general recommendation gives advice to develop a favourable regional framework for policy and legal issues, instigate development of appropriate technologies, promote technology transfers, develop human capacity and create novel systems of financing RE projects.

1.2 Stakeholders of RET

In identifying the range of stakeholders for RET in SA, cognisance is made that this group includes on one hand individuals, groupings, or entities that are involved in the development of RET and on the other hand the ultimate beneficiaries that are targeted by any actions of developing RET. Four clusters can thus appear in classifying stakeholders.

Firstly, the general society of SA is a major stakeholder of the in RET, specifically that part which resides in rural areas and forms the larger proportion. The society's stake is underlined by the fact that it benefits from results of RET projects through increased quality and quantity of energy supply and facilities for grid connection or other decentralisation energy systems embodied in mini-grids. Secondly, the economy of the SA region is part of the consideration through the stimulation provided by RETs. It is foreseen that such stimulation can also be engaged in joint RET projects through North-South and South-South cooperation. Thirdly, the industries and organisations in SA get stimulated by innovative activities of RETs in both a direct and indirect manner, and the outlook for this aspect is bright. Lastly, the research community in SA benefits from RET programmes which are appropriately designed to meet local needs and sensibilities.

1.3 Research in RET

The importance of research in, and eventual development of, RET has been clearly underlined in notable investigations (ISPRES, 2009). The effective response of the RET research agenda is one fashioned with a view to target the appropriate stage of the innovation chain, with differentiated perspectives such as short (e.g. less than five years), medium (e.g. 5-15 years) or long (e.g. greater than 15 years) term views. The response must also be primarily to gain advantage in the energy market without recourse to subsidies and additionally contribute to improvement of technology performance in a sustainable manner.

In the context of a global view (IEA ETP, 2010), the future direction of research in RET ought to lead into increased research in a broad range of regions. In doing so there ought to be more focussed research that accounts for variations in the technologies but also embraces cross-cutting elements that help the contribution of RE to a sustainable energy system. A practical approach to reach this situation is to devise strategic research agendas which have clear roadmaps and are infused with definite milestones.

The current local regional situation in SA is that research and higher education institutions such as universities use research agenda which are not in line with national agenda or national policies. Instances have been recognised where RETs are clearly a more viable solution to energy problems for remote areas away from the grid and may prove to be more reliable than on-grid solutions. By comparison, diesel or other fossil fuels are more expensive than solar solutions. Although some RETs may prove to be currently expensive they are however easier to deploy than other technologies based on fossil fuels and on-grid connections. When a full on-grid solution is proposed for a rural remote area there may be questions raised about the economical viability and such solutions and many such projects tend to end in failure if there is no support of subsidies.

1.4 Outline of the presentation

This presentation begins with an introduction in section 1 which puts in context the problem of research in RET in SA, and is followed in section 2 by description of a methodology that was employed to gather the results of this work. The subsequent section 3 then presents the results of the findings, from which a way forward is devised as presented in section 4. The conclusions are finally given in section 5.

2. Determining RET Research Needs

In determining the research needs for the SA region this work predominantly uses the approach of eliciting information from focus group discussions. The investigators were aware of the option to develop questionnaires which could be administered to stakeholders described in the previous section, but opted for the focus group method because of the opportunity presented by the section of the research project called Network for Energy Excellence in Development (NEED) (Hüneke, 2014) whereby a representation of various stakeholders had in one venue and at the same time. The other benefit that the focus group method had over the questionnaire method was that the investigators were presented a chance to directly clarify the formulated questions to the participants and this ensured a more uniform understanding and interpretation of the questions. In this work two approaches of focus group method of collecting information were applied. The first method was the more innovative World Café method (Schieffer *et al*, 2004), which was applied to a group of varied stakeholders at a three-hour meeting in Zambia in 2014, while the second method is the ordinary focus group method fashioned roughly by the specification of Nagle and Williams (2013) and set off by discussions with representatives of higher education institutions of Botswana, Germany, Botswana, Namibia and Zambia.

2.1 World café method applied to meeting in Zambia

A classification of stakeholders meeting in Lusaka, Zambia in March 2014 appears as in table 1. Schieffer *et al* (2004) fully describes the approach applied in the World Café method and this work largely applied this method to the assembly of 31 individuals which was at any time distributed in a four groupings over four large expansive stalls.

Table 1: Classification of stakeholders at Lusaka World Cafe meeting-2014

	Stakeholder class	Number
I	Governmental or quasi-governmental	3
II	Energy producers and /or suppliers	2
III	Higher education and/ or research or training institutions	14
IV	Energy consultants	4
V	Renewable energy installers and/or RE equipment vendors	5
VI	RE associations	2
	Total	31

While the field of representation for all the seven classes shown in table 1 was wholly from Zambia, the representation for class III (Higher education, training or research institution) had the inclusion of representatives from Botswana (4), Germany (3) and Namibia (3).

The question that elicited the RE research needs in SA was posed with varying tones as guided by the leader of each stall, as in the sub-themes below:

Stall 1:- Research strategies;

Stall 2:- RE industry standards;

Stall 3:- Education dual-studies;

Stall 4:- Off-grid applications.

2.2 Ordinary focus group method applied to meeting in Namibia

A regular focus group method fashioned on the description of Nagle and Williams (2013) was followed for the meeting in Gobabeb, Namibia in March 2015. The 12 participants, all from higher education and research institutions, were divided into three groups for focussed discussion on the question "What are the RE research capacities of your institution?". Table 2 shows the representation of the higher education and research institution at the meeting.

Table 2: Participants at Gobabeb meeting-2015

	Stakeholder class	Number represented
I	Botswana International University of Science and Technology	3
II	Ingolstadt University of Applied Sciences	3
III	Okavango Research Institute (University of Botswana)	1
IV	Polytechnic of Namibia	3
V	University of Zambia	2
	Total	12

2.3 Aggregation of information

The information collected from the discussions at the two meetings in Lusaka (in 2014) and Gobabeb (in 2015) was then qualitatively analysed and classified to produce a draft formulation of requirements for research in RE for SA. After sharing the findings of this draft report with a section of external stakeholders in Zambia, the draft report was presented and further discussed at the meeting in Palapye, Botswana, which consisted of the participants indicated in Table 2. The result was a definitive report that identifies the research requirements for RETs in SA.

3. RET research needs

Following inquiry into research needs for the SA region, anchored by the two workshops of stakeholders in Zambia and Namibia in 2014 and 2015, respectively, a perspective has emerged where four broad areas of research in the short term (up to 5 years) have been identified. The four areas identified are (1) Solar Energy, (2) Bio energy, (3) Control Aspects, and (4) Cross-cutting Issues. The next subsections give an elaboration and elucidation on these findings.

3.1 Solar Energy

The SA region is well-poised to take advantage of the abundant energy resource from the sun. The average daily insolation on the surface for this region exceeds 5 kWh/m²/day compared to less than 1 kWh/m²/day for Germany (SolarGIS, 2011), yet Germany is able to avail a capacity of 40 MW of photovoltaic power on a land mass which is less than 5% that of the SA region.

As an immediate response to have high impact on the economies of SA countries it is suggested that research in the region in solar energy should avoid being encumbered in the developments at device level in solar cells and solar collectors, which is well developed in the lead of developed nations of the West, Japan and China, but rather concentrate on developments at component level for applications in photovoltaic and solar thermal deployment. Thus solar research at component level should lead to devising more effective systems for both photovoltaic and solar thermal applications in the SA region.

One overlooked aspect of existing systems is the integration of functional systems exploiting the full potential of the solar resource, and thus there is a strong suggestion to have integrated systems that have

functions of producing both photovoltaic and solar thermal in one unit. The possibilities that, for instance, shall produce a single unit which produces both hot water from direct solar heating and electricity from photovoltaic activity should not escape imagination.

3.2 Bio energy

Bionergy resources, characterised by the forms of solid, liquid and gaseous biomass, are abundant in the SA Africa region with room for extensive exploitation for production of clean energy. Research institutions in SA are starting to have an appreciable handle on technologies that exploit this resource and are able to give a unique interpretation of the current inroads of the leading research. The findings in this study have given a strong suggestion to devise new ways of exploration of the resources and to uncover innovative uses and applications of biofuels, and gaseous and solid biomass.

3.3 Control Aspects

Hybrid systems incorporating combinations of solar, biomass, geothermal and wind energy open up new and attractive areas for research in the SA region, especially that the current state of technologies yield relatively low capacity factors to all these types of power plants with the exception of biomass. While plants powered by solar and wind energy are commonly used as peaking plants, overall capacity factor can be sufficiently increased when used in combination to result in high availability. Considered in this way, the need to devise control systems that enable the reliable and effective use of combinations of resources is apparent.

The implementation and operation of micro and mini grids, especially with the deployment of hybrid energy sources, require new insights especially when uncharted applications are encountered as happens in usage in rural areas of SA region.

3.4 Cross-cutting Issues

Apart from hybrid systems, which have been considered separately in the previous section, there are evidently matters of interest of research which cross over the realm of each of the RE resources mentioned and also over other the realms not traditionally connected with RE, such as economic and social aspects. In this study strong credence emerged in the discussions to consider conducting new case studies for validation of previous work that mapped the use and application of RE, which may now be considered as stale due to having employed what are outdated systems, methods and technologies. In the similar vein, there is a need to revisit studies that indicated the future projection of the RETs, considering that new markets and regions were not considered in those early studies.

Energy management and energy storage are subjects that will continually engage researchers even in the SA region, as appropriate and more effective solutions are sought. Systems in the value chain from design to implementation present a special niche of studies applicable to the region, with the goal to churn out cost-effective RE systems.

One issue which bogs down implementation of projects, especially large ones, is overruns on cost and times. As the outlook for the regions seems to suggest increased activity in producing RE projects, it emerged from the workshop discussions that studies for the formulation of policies that assure success of RE projects are inevitable.

4. Way Forward

The SA region is made up of no less than ten countries. Despite the identification of the four main areas of research for RET with the appearance of being common to the region, there is a high possibility to have a divergence of priorities in the countries involved due to variations in the broad visions. One way to create and substantially guide development in one common direction, such as having a common research agenda, is for the countries to use the avenue provided by the newly created SADC Centre for Renewable Energy and Energy Efficiency (SACREEE). This work advocates the involvement of political and economical regional groupings such as SADC to set up mechanisms to establishing and supporting such a regional centre of excellence in RET for sustainable development. It is appreciated that one influence which SADC can have in the development of the SA region is to give concordance to a time-view of development with a specification of short, medium and long term goals which are pursued in unison.

There is a concerted effort under NEED, with one of the four objectives devised to develop RE research strategies for the SA region. Once a research roadmap is fully devised and adopted from this work, the intention is to further specify the mechanism for institutionalising the common roadmap into public decision-making arrangements of the policy bodies of the countries of the region. This initiative passes off as the groundwork from which can spring the activities of the regional centre of excellence in RE under SADC.

5. Conclusion

This paper has revealed four major themes as immediate requirements for research in RET in SA, namely solar energy, bioenergy, control aspects and a group of themes cutting across these three RE themes and also into other disciplines outside RET. The research requirements were teased out mainly through two discussion sittings of focus groups composed of pertinent stakeholders in SA and in Europe. It has been observed that RET research in SA will have realistic impact if the countries in the region all adopt the indicated areas of research as their requirements in the short term. One way to achieve this is to establish and work through the structures of SACREEE. The activities of the NEED project are recognised as presenting a good facility to identify the common direction for research in SA, and the final recommendations when the project is concluded should be of interest to policy makers in the region.

Although this work has revealed the research requirements for RET in SA for the next first five years there is need to identify the needs for the medium and long term periods reaching up to 30 years.

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Dual Studies - An Alternative Pedagogy for Renewable Energy Training in Southern Africa

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Abstract

Striking the right balance between theoretical and practical studies in academia is generally not an easy thing especially when implementing a new programme. With the continuous decline in production and supply uncertainty of fossil fuels, renewable energy curricula and technologies are taking centre stage. This elicits for the development of an alternative pedagogical approach, of dual educational programs, that combines both theoretical and practical training for technicians and engineers. The dual studies approach has worked well in many European countries and is proposed as the right mix for Southern Africa, in general, and for renewable energy technologies (RETs) in particular. RET training needs surveys were conducted and a curriculum framework and structure for dual studies for the vocational and professionals has been developed for the region. A strategy has also been developed to promote science and renewable energies among young people. It was observed that the dual study approach was warmly welcomed by the respondents, but industry participation holds the key to its success. Because of the need to bridge the identified skills gap, industry was also ready to join hands with academic institutions in the region for training in RETs.

Keywords: capacity building, dual studies, NEED, pedagogical, renewable energy technologies

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1. Introduction

The dual education system is a combination of apprenticeship at a company and vocational education at a Vocational Training Centre. It is widely practised in Europe, notably in Germany, Austria, Switzerland, Hungary, Bosnia/Herzegovina, Slovenia, Serbia, Denmark and the Netherlands. It goes a step higher than the normal stream of studying with internships or experiential training as the candidates are regarded as studying and working at the same time as they can spend up to half the total time at the company (Göhringer, 2002).

In Germany, dual studies are mainly offered at the Universities of Applied Sciences (UAS) and Universities of Cooperative Education (UCE) or *Berufsakademie* but very rarely at the (traditional) universities. In fact UCE's are universities that offer only dual studies in all the major disciplines except the Artistic courses and the Humanities.

A limited number of dual study programmes are offered in the target region (Namibia, Zambia and Botswana) analysed by the authors. In Namibia, the Namibia Institute of Mining and Technology (NIMT), which offers various vocational programmes, including solar RET, offers dual education system. The Mazabuka Vocational Skills Training Centre also offers some dual programmes in Zambia.

An online survey was conducted in the target region to investigate RET training and training needs and also the possibility of going the dual study approach especially at vocational (craft) level. Among the respondents were businessmen in RETs, government officials/policy makers in energy, students studying energy, vocational school instructors. The results of this survey are not in the scope of this paper but it suffices to mention that there was widespread enthusiasm about the introduction of dual studies in the target region (Zulu, 2015).

The rest of the paper is structured as follows: Section 2 gives a brief summary of the advantages of the dual education approach but also touches on its disadvantages. Section 3 gives the proposed curriculum framework and structure for dual studies. Section 4 briefly describes the activities of a European Union (EU) funded project that promotes RETs and dual study programmes. Section 5 briefly describes some efforts for capacity building in RETs in the target region; and section 6 gives concluding remarks.

2. The Dual Study Edge

The dual study education system is credited for better preparing students for the world of work, giving an easy transition from student life to working life. It also brings independence to the student as they are more financially stable and can pay school fees themselves. Former Germany's labour minister Ursula von der Leyen pointed out that the two countries with the lowest unemployment in Europe (Germany and Austria), especially among the youth are directly because of the dual education system (The Economist, 2013).

The disadvantage of the dual system is that for research oriented learning, not much theory can be covered compared to the non-dual study system in relative terms. Also, the success of the system depends on the availability of participating companies that may be going through an economic downturn and may not be willing to take students (Koudahl, 2010).

A more detailed analysis of what has been observed from implementing dual study programs over the years is found in a newsletter of the Germany Federal Institute for Vocational Training (BIBB) and is summarised in Tables 1 and 2 on the next page.

Table 3: Ranking of the advantages and disadvantages of “dual” training measures based on an international comparison (Federal Institute of Vocational Training – BIBB [2002])

Advantages	Disadvantages
1. Mixture of learning venues is enhanced through practical experience	1. Training schemes dependent on economic climate create problems
2. Trainers' knowledge of the latest technical developments is updated	2. Difficulties in implementing curricula when the workplace only offers limited learning opportunities
3. Social partners have more opportunities to influence the shape of training	3. Technical changes which impact training are implemented in the company and school at different speeds (“time lag”)
4. Productive work increases trainees' motivation and reduces the costs for the training companies	4. Heterogeneity of companies' learning schemes leads to qualitative problems in training
5. Inter-company training centres, as additional learning venues, can iron out deficits of practice-related learning	

Table 2: Ranking of the advantages and disadvantages of “dual system” in Germany from the angle of German experts (Federal Institute of Vocational Training – BIBB [2002])

Advantages	Disadvantages
1. Recruitment of their own expert staff through training is advantageous for companies (no situations vacant, no risk in filling positions, no induction, etc.)	1. Training market does not always cover training demand
2. Learning venue mixture has positive effects on training	2. The quality and quantity of training depends on the training willingness of the companies
3. Quality of training results from the compromise between company- and occupation-specific qualification	3. State must co-finance training without being able to control it
4. High social acceptance of training, hence positive image of training companies	4. Cooperation deficits between teachers and in-company trainers
5. Cost reduction for companies through productive input of trainees	5. Considerable formal input to safeguard system infrastructure
6. Pressure for schools to adapt because they must face up to the requirements of practice	6. No transferability guaranteed between initial and continuing training
7. Widely accepted qualitative minimum standards	
8. Easier transition from training to an occupation (“second threshold”)	

3. Dual Study Proposed Curriculum Framework and Structure

3.1 Proposed Curriculum Framework

The proposed curriculum framework for RET covers solar and wind technologies at vocational level as these are the abundant resources in the target region and vocational skills are the most lacking skills in the target region. Note that the indicated levels are aligned with the Unit Standards Framework for Vocational Training for the Namibia Training Authority and roughly aligned with Bloom's taxonomy. The framework is divided into two parts: what students should be able to know and what students should be able to do (Zulu, 2015).

What Students Should Know

- Safety
- Administrative, legal and finance aspects
- Basic electricity especially A/C principles
- Basic plumbing principles
- Solar PV, PVP, SWH, Wind Technologies
- Energy storage technologies
- Basic principles of thermodynamics
- Basic principles of fluid mechanics
- Environmental and sustainability issues related to solar and wind installations
- Basic and advanced measuring instruments
- Computer literacy and application skills

What Students Should Be Able To Do

Level 1 (Apply and interpret)

- Apply safety and applicable regulations
- Perform administrative duties
- Draw, interpret and apply basic and advanced technical drawings
- Utilise RET specialized computer applications
- Use and maintain electrical and mechanical tools and measuring instruments – including estimation and calculation.

Level 2 (Install)

- Install basic & advanced Solar Home Systems (SHS)
- Install basic & advanced Photovoltaic Pumping (PVP) systems
- Install basic & advanced Solar Water Heater (SWH) system with pre-heating
- Install basic & advanced Wind Energy System
- Prepare mounting structures.

Level 3 (Maintain and troubleshoot)

- Maintain and troubleshoot Solar Home Systems (SHS)
- Maintain and troubleshoot Photovoltaic Pumping (PVP) systems
- Maintain and troubleshoot Solar Water Heater (SWH) systems
- Maintain and troubleshoot Wind Energy systems
- Demonstrate special PV applications (hybrid & grid-tied)
- Manage business, financial & legal aspects of an RET business.

Level 4 (Design and commission)

- Design basic and advanced Solar Home Systems (SHS)
- Design basic and advanced Photovoltaic Pumping (PVP) systems
- Design Solar Water Heater (SWH) domestic systems
- Design basic & advanced Wind Energy Systems
- Design and manufacture mounting structures
- Commission Solar Home Systems (SHS), Solar Water Heater (SWH), Photovoltaic Pumping (PVP) systems.

Figure 1 is a pictorial view of the philosophy behind the proposed curriculum framework.

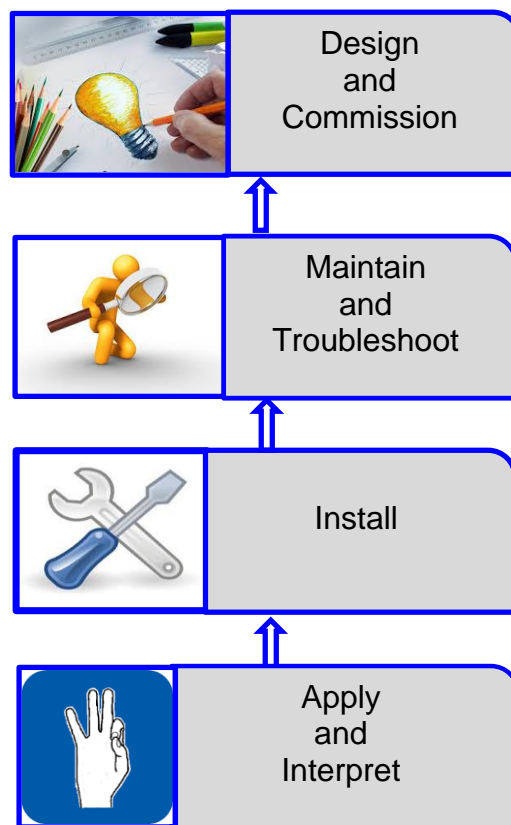
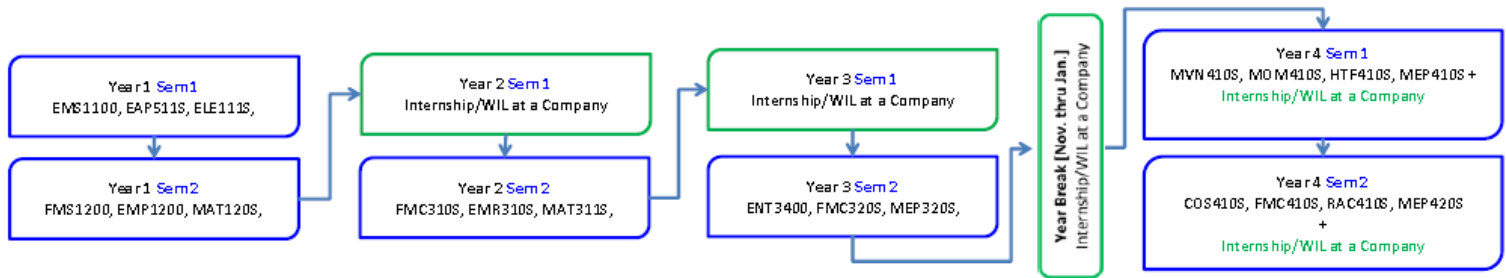


Figure 1: Proposed RET Curriculum Framework (Zulu, 2015).

3.2 Proposed Structure

Figure 2 shows the proposed structure of dual studies with specific case of the Bachelor of Technology (B.Tech) programme at Namibia University of Science and Technology.



Proposed RET Curriculum Framework (Zulu, 2015).

4. NEED Project

The Network for Energy Excellence for Development (NEED) Project is funded by the European Union and runs for a period of three years from 1st March 2014 to 28th February 2017. The NEED Project is a synergy in RETs between the following four universities and one research centre: Technische Hochschule Ingolstadt (THI in Germany); Namibia University of Science and Technology (NUST in Namibia); University of Zambia (UNZA in Zambia); Botswana International University of Science and Technology (BIUST in Botswana); and Okavango Research Institute (ORI in Botswana). The main objectives of the NEED Project in RETs are (Hüneke M. et al, 2014): pooling of research activities; the development of dual study programs; the harmonization of industry standards; and the development of two energy concepts for remote areas, a dryland and a wetland.

Within the NEED Project, NUST is tasked with Work Package 3, which deals with dual study programs. The first objective of Work Package 3 is to analyze existing vocational training and training needs in the partner countries. The second objective is to develop the structure and framework of dual study programmes. The third objective is to institutionalise a culture of science to promote RETs among young people. The different Work Packages and how they fit together (Project Structure) is shown in Figure 3 on the next page.

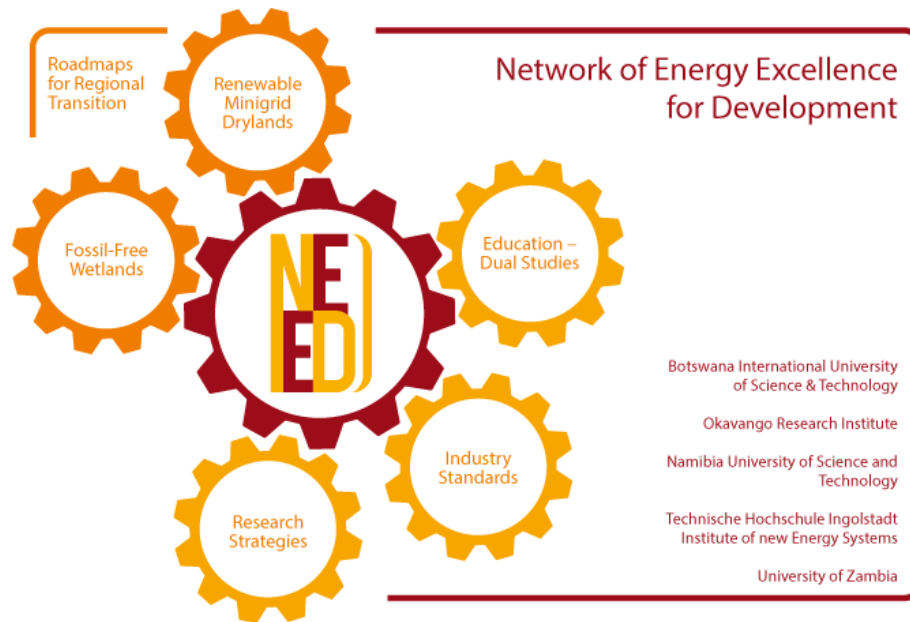


Figure 3: NEED Project Structure (www.need-project.org).

5. Capacity Building in RETs in Southern Africa

Several initiatives have been instituted for capacity building in RETs in target region of this study - Namibia, Zambia, and Botswana. Institutions and universities in these countries offer various training programmes and qualifications in RETs, mainly in solar and wind energy. RETs have gained momentum in the recent past due to power load shedding in Botswana and Zambia, with Namibia at the tipping point importing more than 60% its power from neighbouring countries (Zulu et al, 2015).

In addition, government regulatory bodies have introduced policies to ensure sustainability in capacity building in RETs. It is observed that despite the efforts made by these countries, the region still lacks skilled personnel in RETs and much remains to be done to increase the skills capacity, refer to reports by (Michael E, 2014) and (Jain P.K, 2008 et al).

International aid agencies and non-governmental organisations have also played a major role in promoting RET's in the region. This is in form sponsorship of existing initiatives and also creating their own initiatives. The most notable contributions are from the European Union (e.g. NEED Project), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Austrian Development Cooperation (through SOLTRAIN).

6. Conclusions

The target region is in desperate need for skills in RETs especially at vocational level. The proposed implementation of dual study programmes, synergy between academia and industry, by the NEED project; will go a long way in addressing this lack of skills. The implementation strategy is contained in the proposed curriculum framework, which will mainly be for solar photovoltaic, solar thermal and wind energy technologies. Dual studies in general and RETs in particular are posed to boost the region's much needed power output, its economy and its people's welfare.

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Development and Harmonization of Renewable Energy Technology (RET) Standards in the SADC Sub-Region

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Abstract

The Southern African region is endowed with abundant renewable energy resources. However, the lack of access to sufficient and sustainable energy supply still affects most of the region. A number of factors hindering a widespread uptake of renewable energy technology have been identified in technical literature. These include a lack of: skilled human resources, clear policies and strategies to promote Renewable Energy Technologies (RETs), financial mechanisms, and relevant RET standards in the region. The paper will focus on the latter and considers the Southern African Development Community Cooperation in Standardization's (SADCSTAN) pathway for development and harmonization of RET standards in the Southern African region. A multiple case study methodology was adopted to compare the SADCSTAN model to the European model which is more established and successful at harmonization of standards. Similarities were observed between the two models; however, the number of standards that have been harmonized at regional level through SADCSTAN is low and non-existent in some fields such as RETs. The overall objective of the study is to identify and mitigate factors that might be attributed to the delay in development and adoption of harmonized RET standards in the Southern African region.

Keywords: renewable energy technology, standards development, harmonization, SADC, NEED⁹

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1. Introduction

The Southern African region continues to be over dependant on conventional fossil fuels. Despite the huge potential, renewable energy technology (RET) contribution is insignificant to the energy mix in the region. According to IRENA (2013), Katende et al. (2016) coal is the main energy resource in South Africa, Botswana and Zimbabwe while natural gas is the primary resource in Tanzania and Angola. The rest of the region relies predominantly on hydropower.

Coal, natural gas and petroleum products are the main energy resources in the region. This brings challenges that are posed by high depletion rates, environmental degradation and air pollution associated with the burning of the fossil fuels. The demand for energy has also exceeded the supply resulting in frequent power outages in the region. This situation presents an opportunity for the uptake of RETs in the region. According to Mwansa et al. (2015), the current share of RE is distributed among traditional biomass (94%) that is primarily used for cooking and heating, hydro 5%, and modern biomass (1%). The extent to which the traditional biomass can be classified as renewable will remain debatable as this usually involves an uncontrolled collection and burning of wood fuels which may lead to land deforestation and desert encroachment. The contribution of renewable energy sources such as solar, geothermal, wind and biofuels remain negligible.

A number of factors that undermine the development and application of RET have been identified by several authors Katende et al (2016) and Zorner et al (2014). These include the absence of enabling policies, limited technical know-how and a lack of sufficient skilled workforce, and a lack of harmonized RET standards in the region. The Network of Energy Excellence for Development (NEED) was formulated to address some of these issues that impede the uptake of RETs in the region. NEED is a consortium of five partner institutions from Botswana, Germany, Namibia and Zambia that are undertaking collaborative research aimed at institutionalizing the widespread exploitation of RE resources in the Southern African region, Katende et al (2016). The project comprises of seven Work Packages (WPs). WP1 and WP7 are responsible for the overall coordination and administration of the project, and interfacing with the project sponsors. WP2 deals with formulating research policies, WP3 is concerned with enhancing practical education ('dual studies') while WP5 and WP6 deal with identification of RET models for wetlands and dry lands. Lastly WP4, is concerned with the development and harmonization of RET industry standards in the region. The content of the paper is from part of the work that is being carried out by WP4.

2. Methodology

The case study methodology was used to facilitate exploration of the phenomenon of developing a harmonized framework within the context of the study region using a variety of data sources. Document analysis and direct interview were adopted as a way to determine data. The study was guided by the following research questions:

- Are there existing harmonized frameworks for standards development in general?
- What are the components of the identified harmonized framework?
- How do the identified frameworks compare?
- What is the relation between the harmonization of standards and the uptake of a technology such as RETs?

The European Committee for Standardization (CEN) framework was compared to the South African Development Community Cooperation in Standardization (SADCSTAN) model. The choice of the CEN model was motivated by the success the European countries have attained so far in spite of relatively subdued RET resources, especially solar energy. For the analysis of data obtained, the focus of the study was to briefly seek for: pattern matching, linking data to propositions, explanation building, logic models, and cross case synthesis.

3. Development of Standards in the SADC region

A standard is a repeatable, agreed and documented way of doing something, SABS (2016). The availability of standards is important to:

- Enable businesses to make their products and services comply with a set of existing legislation CEN (2016) and provide the businesses/industry and users with the framework for achieving greater product and service delivery.
- Ensure safety, reliability, human health and protection of the environment.

Most countries in the world have National Standards Bodies (NSBs) that are tasked with development of country national standards and coordinating quality assurance activities. These institutions also affiliate to the International Organization for Standardization (ISO) which is a worldwide federation of NSBs. The mission of the ISO is to encourage the development of standardization and related activities in the world in order to facilitate international exchange of goods and services, BOBS (2016).

The development process of national standards in two Southern African countries (Botswana and Zambia) is presented in Figure 1 and Figure 2, respectively.

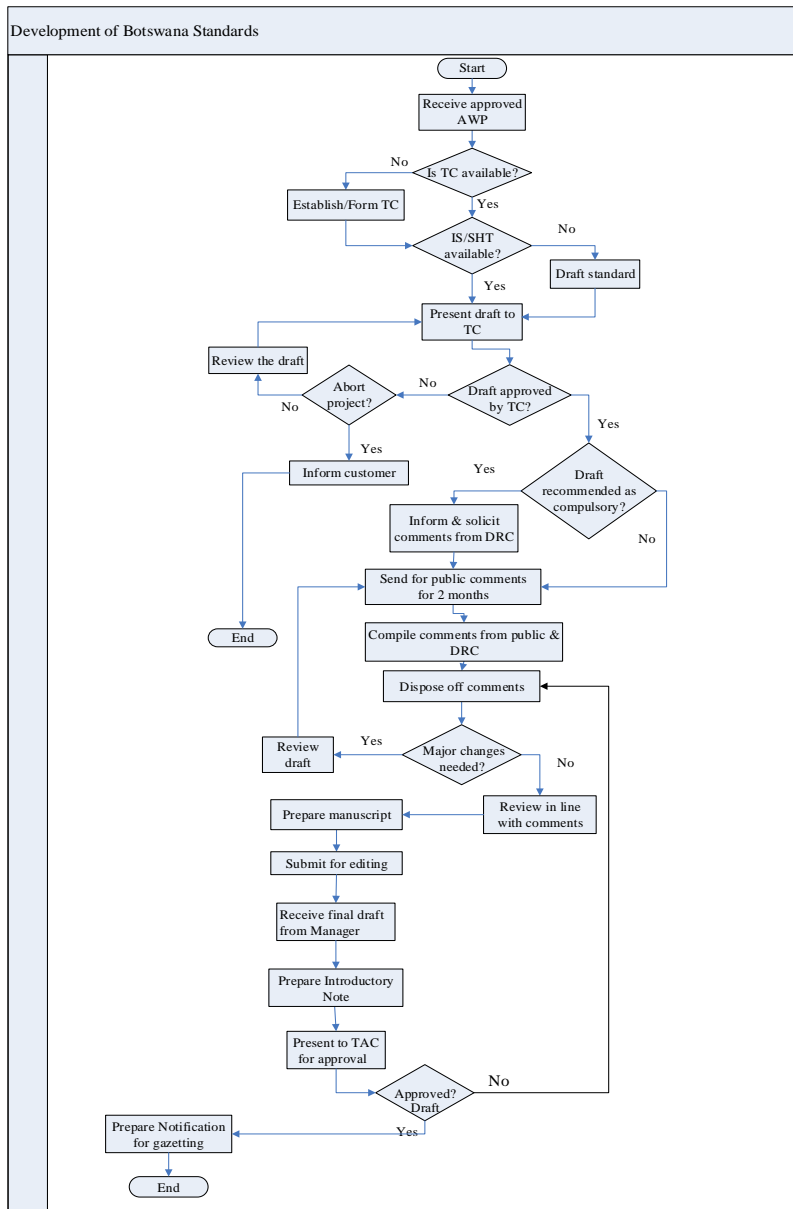


Figure 1. Standard development process in Botswana, BOBS (2016)

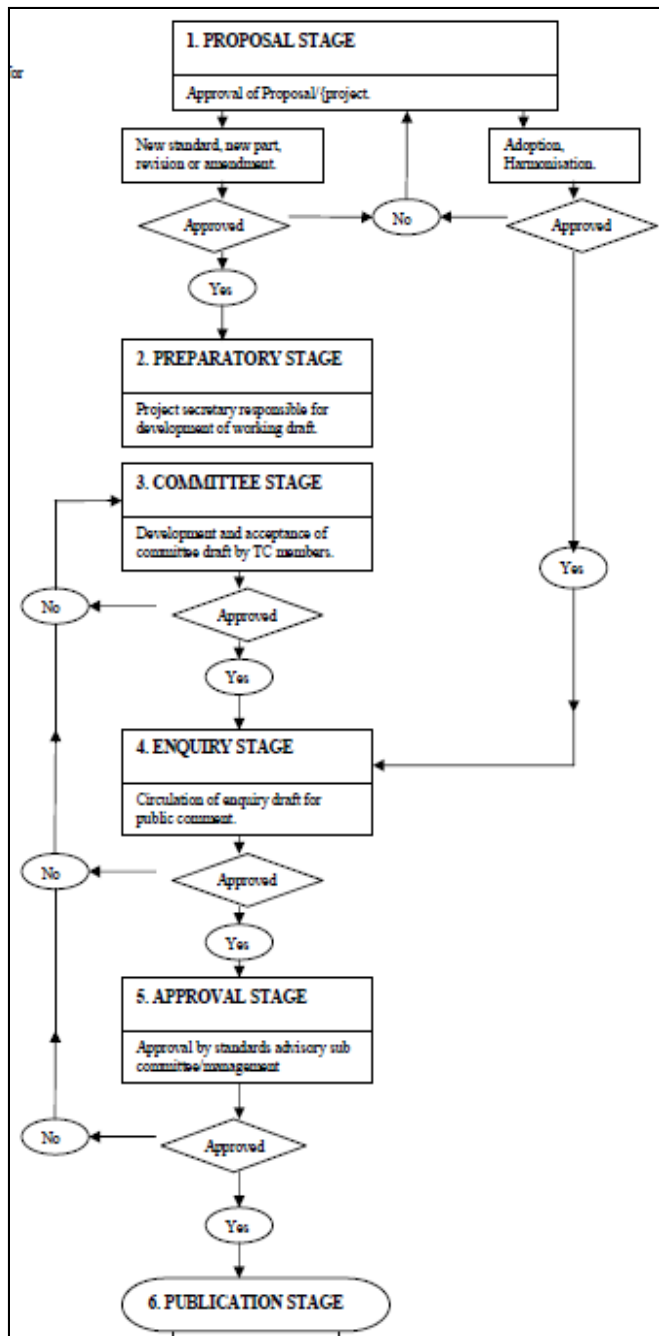


Figure 2. Standard development process in Zambia, ZABS (2016)

Figures 1 and 2 illustrate the processes of developing standards in two Southern African countries, namely Botswana and Zambia, respectively. The Botswana standardization process seems more detailed but, the processes are generally identical between the two countries. This is also similar to what occurs in other countries and a summary of the Standards Development Life Cycle is presented in Figure 3.

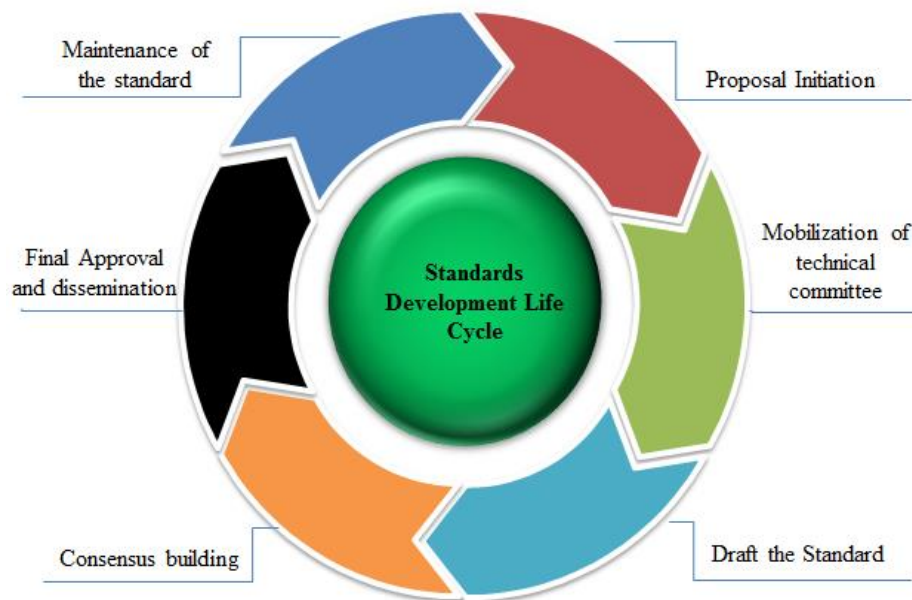


Figure 3. Procedure for development of standards

The standard development stages include the proposal stage: a standard is proposed and approval sort; preparatory stage: a Technical Committee (TC) is formed which creates a work plan and starts the drafting of the standard; consultation stage: the draft goes for public comments; approval stage: the final standard is approved, publication stage: the standard is published; maintenance: continuous review of the standard for its relevance.

4. SADCSTAN

The Southern African Development Community (SADC) was formed in 1992 when a treaty was adopted to redefine the basis of cooperation among member countries from a loose association into a legally binding agreement. It is made up of 15 member countries in the Southern African region with a population of over 200 million people. Its main objectives are to achieve development, peace and security, and economic growth, to alleviate poverty, to enhance the standard and quality of life of the peoples of Southern Africa. One of the important SADC integration milestones is the establishment of a Free Trade Area (FTA) in the region which was achieved in 2008. The purpose of the FTA is to create a larger market, improve trade and stimulate economic growth and employment creation, SADC (2016). For the establishment of a successful FTA, it was necessary that product and service standards be developed and harmonized in the region.

4.1 Importance of harmonization of standards

Harmonization consists of both standardization and policy alignment. In the context of the current study, standardization implies high quality and security of supply of technology for various RETs. For example, standardization includes integrity of the physical components of a RET plant and system reliability. The issue of policy alignment to promote harmonization deals with various political and operational matter such as legislation and regulatory structures to deploy renewable energy resources.

The broader issues of tariff reform, environmental, economic and social impact, and coordinated resource planning, and management are also important for a harmonized RET sector, SADC (2016).

The development, harmonization and availability of RET standards are very necessary as already discussed, CEN (2016) and SADCSTAN (2016) for the following reasons:

- Harmonized standards ensure the compatibility of different components, products and services, CEN (2016)
- Harmonized standards encourage a freer flow of goods and services within the region and thus facilitating trade.

SADCSTAN was established in 2008 as a Technical Barriers to Trade (TBT) Annex to the SADC Protocol on Trade. Its objective is to promote the coordination of standardization activities and service in the region, with the purpose of achieving harmonization of standards and technical regulations, SADCSTAN (2016). The SADCSTAN harmonization work is driven by the need to support regional development through trade facilitation, by technical regulations for health, safety and environmental protection. The SADCSTAN membership is divided into ordinary, associate and stakeholder categories. The ordinary membership is open to National Standards Bodies (NSB) of SADC member countries or any local institution designated by the relevant Minister for Trade and Industry in the country. Associate members are institutions or non-SADC member states which meet the criteria of ordinary membership while stakeholder members include industry associations, government representatives, standards developing organizations, and others.

A committee consisting of one delegate from each member state in SADC ensures that the functions of SADCSTAN are pursued pragmatically. The committee is led by a Chairman, who is selected among the ordinary members and serves on a rotational basis for a period of two years. The Secretariat is established at a designated member NSBs to carry out the day to day activities. The term of office for the Secretariat is for three years. A Standards Management Committee (SMC) is also appointed by the Executive to handle specific issues relating to standards development and harmonization. SMC appoints technical committees (TCs)/ subcommittee (SCs) and approves their work programs. The Chairmanship of the SMC is also rotational.

4.2 The process for standards development at SADCSTAN

The process for standards development at SADCSTAN is outlined below;

- A proposal for a harmonization project may be made by any person or body in any SADC country but it has to be routed through that country's NSB which shall in turn submit it to the SMC for consideration.
- Any project or published standard that is identified suitable for harmonization is referred to a TC/SC in whose field the activity of the project falls. In the absence of such a TC/SC a proposal to establish one may be made, via the SADCSTAN Secretariat, to the SMC for consideration.
- Each TC/SC reports quarterly progress to the SMC.

4.3 Technical Committees (TCs) and SADCSTAN Harmonized Standards

Table 1 shows the various SADCSTAN technical committees and the TC secretariats. The table is used as a guide since harmonization and development of standards is carried out on an ongoing basis. It can be seen from the table that the number of standards that have been harmonized for the region is

insignificant compared to the total number of published national standards by the different SADC countries. This might be because SADCSTAN was formed after most standards were already developed in the member states. However, it is observed that a lot of work still lies ahead for SADCSTAN in terms of harmonization of existing and new standards. Countries continue to develop standards at national level and SADCSTAN may need to adopt these standards for use in the region. It has been laid out in the SADCSTAN principles and procedures that harmonized standards are obligatory to the SADC members and any conflicting national standards have to be withdrawn. As such the SADC member countries should be focusing more on development of standards through the SADCSTAN route and not at national level. This will also reduce on the duplication of efforts.

Seemingly, there are no RETs standards that have been harmonized at the regional level. Malawi has recently been appointed to serve as the secretariat to TC16 – Energy, for developing standards on fossil diesel fuel, unleaded petrol and biodiesel fuels.

Table 1. Allocation of Technical Committees (TC's) and Secretariats, SADC (2010/2011)

TC No.	TC Name	Harmonized Projects (incl. those due for revision)	Country	No. of National Standards published**
1	Construction	6	Botswana	600
7	Packed Goods			
2	Automotive and Transportation	33	South Africa	6100
8	Hospitality and Tourism			
4	Electro-technical	5		
15	Globally Harmonized System	2		
3	Foods and Agriculture	2	Mauritius	217
6	Health and Safety			
9	Non-Destructive Testing			
5	Environment	3	Zimbabwe	1596
10	Conformity Assessment	4		
11	Quality		Tanzania	1132
12	Metrology		Malawi	622
14	Water			
16	Biofuels*			
	TOTAL	55		

The lack of harmonized standards on RETs has been identified to contribute to the slow acceptance and application of RETs in the region, since standards provide industry and users with a framework for achieving greater product quality and reliability and therefore improving marketability and uptake of a technology, Katende et al. (2016).

Even though there are no harmonized RET standards in the Southern African region, different countries have developed some RET standards at national level through their respective NSBs. Table 2 shows the number of RET standards in three Southern African countries (Botswana, Namibia, Zambia) compared to those in Germany. The number of RET standards in individual countries in Southern Africa is relatively low when compared to those developed in Germany, which has been successful in deployment of RETs.

Table 2. Number of published RET standards

Country	Number of RET standards
Botswana	16
Namibia	17
Zambia	5
Germany	95

5. Development of standards in Europe

The procedures used by NSBs in Southern Africa and those by SADCSTAN as outlined above in Sections 3 and 4 are fairly similar to those used by countries in Europe. Figure 4 shows the flow procedure in the development of British Standards. The figure has three pathways in the development of the BS standards, namely through ISO as discussed previously, CEN and development at national level. CEN will be equivalent to SADCSTAN in the Southern Africa context.

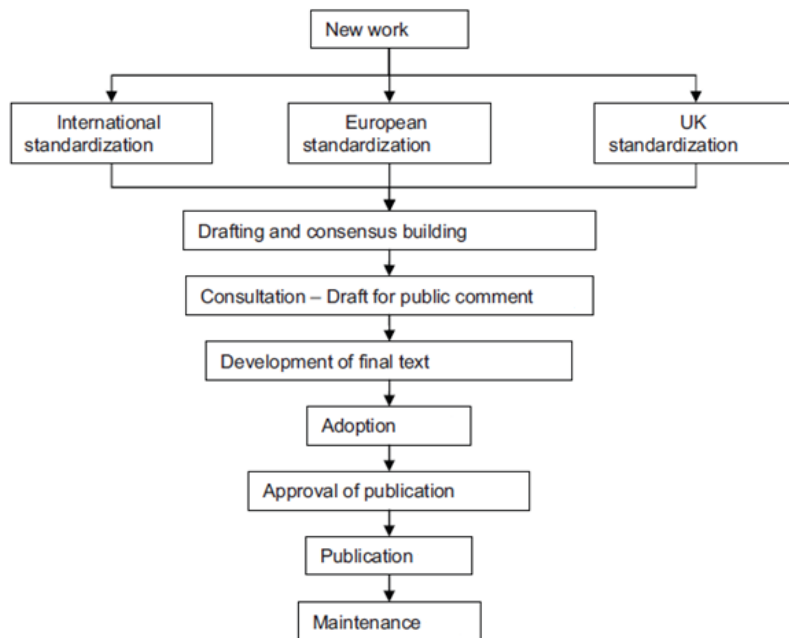


Figure 4. Stages development of British standards (BSI 2011)

CEN, European Committee for Electrotechnical Standardization (CENELEC) and European Telecommunication Standards Institute (ETSI) all work with the European Commission on development of the respective standards at regional level. However the standard development by these institutions is well advanced. This is demonstrated in Table 3 and Figure 5 which show the number of standards and the various fields where the standards are applied respectively.

Table 3. CENELEC active standards (CENELEC 2016)

Active standards	2013	2014	2015
Published standards /year	432	509	463
Total active standards	6372	6519	6685
Net increase at year end	136	147	166

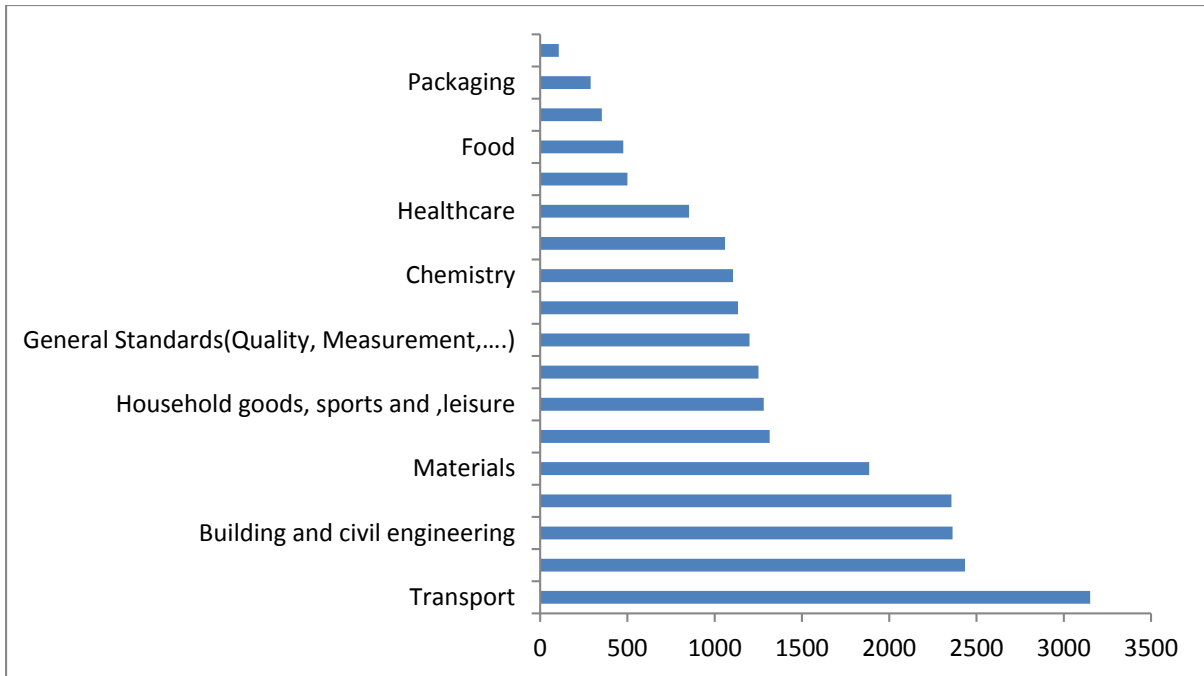


Figure 5. CEN-CENELEC Portfolio per business domain, CEN-CENELEC (2016)

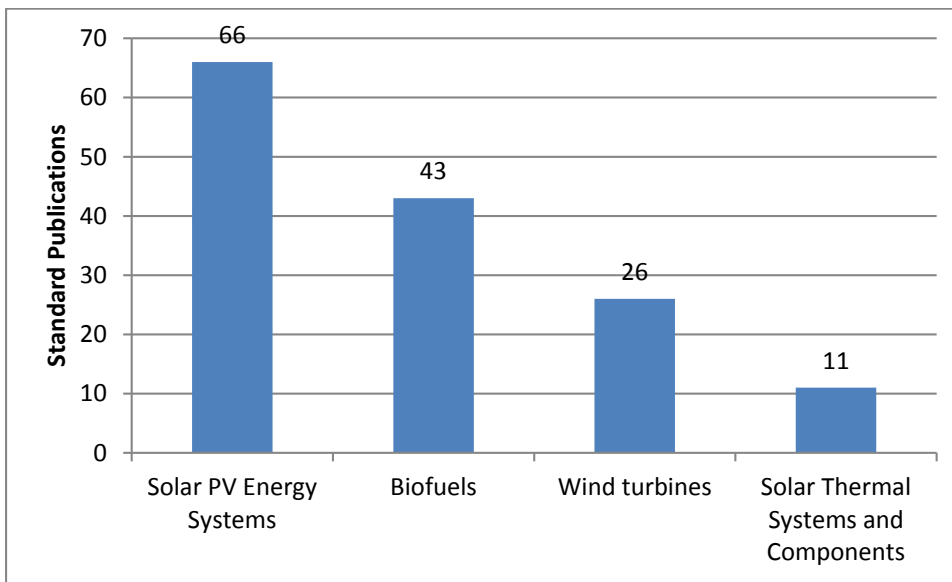


Figure 6. CEN/CENELEC published RETs standards, CEN-CENELEC (2016)

A total of 146 RETs standards have been published by CEN/CENELEC as shown in Figure 6. This means that the European Commission has a higher number of standards in RETs than all the standards published in the various fields by SADCSTAN. This seems to be one of the important factors contributing to the disparity in the application of RETs between the two regions.

6. Promotion of RETs Standard development

In an effort to promote the development and harmonization of standards through SADCSTAN, WP4 has recently formed an association of RET stakeholders, the Renewable Energy Association of

Botswana (REAB). Overall, the association's aim is to support the government's effort and strategy for increasing the role of RETs in the national energy mix. With regard to standardization, the association will regularly make requests to the NSB- Botswana Bureau of Standards (BOBS) for the development and harmonization of applicable standards, in line with a roadmap that is being developed by the work package. It is expected that formation of similar associations will be replicated in other NEED partner countries in the region. The role of NEED, Industry (REAB) and standards bodies in promoting the application of RETs is presented in Figure 7. A strong industry will expedite the development and harmonization of the standards as they promote the sale of their products. The RET industry within the region is small compared to what obtains in Europe and this might be one of the reasons why SADCSTAN is not yet very active when compared to CEN/CENELEC and other regional standardization bodies. Better communication is also necessary amongst the SADC countries, for example all Departments dealing with energy in the different countries should engage themselves regularly to promote development of standards in RETs. Visibility and marketing of SADCSTAN as a pathway is also crucial. Another limitation to SADCSTAN is the lack of testing facilities to monitor quality of products and ensure that standards and codes of practice are being adhered to. This is hampered by a lack of laboratories due to shortage of funds and well trained human capacity. It will be better if such facilities are also developed at a regional level for uniformity of tests and also to conserve the limited resources.

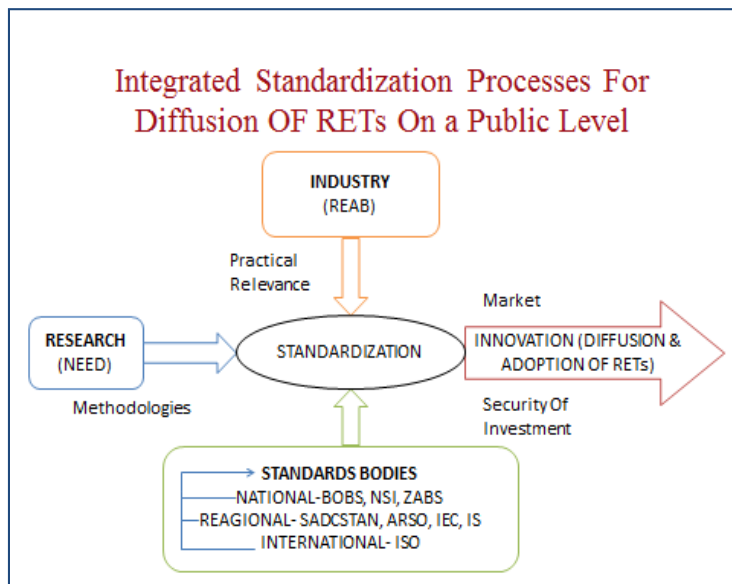


Figure 7. Integrated standardization process for diffusion of RETs on a public level. The figure adopted from German Standardization Roadmap (2016)

7. Conclusions

Creation of SADCSTAN is a novel idea but its performance with development and harmonization of standards in the region is lean. Relatively few standards have been developed and harmonized in the region compared to the national standards developed in the member countries. More effort is needed from the SADCSTAN members and the focus should be harmonization at regional level instead of development of national standards. This will also apply to the development of regional testing facilities given that funds are limited. This will improve trade and facilitate the adoption and applications of

technologies such as RETs which are insignificant in comparison with the abundant renewable resources in the region. The industry, represented by renewable energy associations should also take a leading role in ensuring that more standards are being developed and harmonized.

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Perceptions of Tourism Operators towards Renewable Energy Use in Accommodation Facilities in the Okavango Delta

Joseph E. Mbaiwa*¹, Moseki R. Motsholapheko¹, Donald L. Kgathi¹

Abstract

This paper analyses perceptions of tourism operators on the use of renewable energy in lodges and camps in the Okavango Delta, Botswana. The paper is informed by the concept of sustainable tourism. Both primary and secondary data sources were used in study. Secondary sources include: management plans, policy documents, published and unpublished articles on energy and tourism development in the Okavango Delta. Primary data collection focused on the administration of a structured and unstructured questionnaire to tourism operators. In addition, informal interviews were conducted with key stakeholders of the energy and tourism industries. Results indicate that fossil fuels are largely used in lodges and camps in the Okavango Delta when compared to renewable energy sources like solar power. Much of the fossil fuels used in the Okavango come from petroleum products. Lodges and camps in the Okavango Delta rely on individual diesel generators to meet their energy demands. Fuel wood is also used for bonfires and heating the water. However, some of the lodges have started using solar energy to complement that which is generated from petroleum products. The majority of the tourism operators especially those who have registered for Eco-certification have positive perceptions towards the use of renewable energy particularly solar energy. There is need, therefore, for policy developments that address the lack of renewable energy distribution in the Okavango Delta. Policy development should encourage renewable energy particularly solar energy which is environmental friendly when compared to fossil fuels to achieve sustainable tourism in the Okavango Delta.

Keywords: renewable energy, solar energy, Okavango Delta, fossil fuels

1. Introduction

Tourism is a leading global industry, responsible for a significant proportion of world production, trade, employment, and investments (Pratt, Rivera, & Bien, 2011). Tourism in many developing countries is the most important source of foreign exchange and foreign direct investment (Pratt, Rivera, & Bien, 2011). Wildlife or game viewing and outdoor recreation in protected areas is making nature-based tourism one of the fastest growing tourism sectors worldwide (Goodwin 1996; Mastny 2001; Davenport et al 2002; Balmford et al 2009). Developing countries particularly Africa has become famous of wildlife-based tourism. For example, much of southern Africa's tourist industry relies on national parks, game reserves and other protected areas containing world renowned wildlife, biological diversity and natural attractions (Poonyth et al., 2002). Nature-based tourism is an important export industry and a

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key revenue earner in developing countries such Kenya, Nepal, Tanzania, Costa Rica and Botswana (Eagles, 2003; Alaeddinoglu & Can, 2011). The tourism industry use energy and there is need to ensure that energy use in this sector is sustainable particularly environmentally friendly.

There is a growing consumption of energy in the tourism sector particularly so in travel and accommodation (Pratt, Rivera, & Bien, 2011). The tourism sector largely depends on fossil fuels and this has important implications for global GHG emissions and climate change as well as for future business growth (Pratt, Rivera, & Bien, 2011). Peeters et al (2010), there are several factors which contribute to the increase in energy consumption in the tourism sector, this includes the growth rates in international tourist arrivals and domestic travel; trends to travel further and over shorter periods of time; as well as preference given to energy-intense transportation (e.g. aircraft and car travel over train and bus, and flying first and business class instead of economy.

After transport, accommodation is the most energy intensive component of the tourism industry, through its demand for heating or cooling, lighting, cooking (in restaurants), cleaning, pools and, in tropical or arid regions, the desalination of seawater (Pratt, Rivera & Bien, (2011). Peeters et al. (2010) argue that the general rule of thumb is that the more luxurious the accommodation, the more energy will be used. Studies (e.g. Peeters et al. 2010) indicate that energy use in hotels range between 25 and 284 MJ/guest night. Tourism is estimated to create about 5% of total GHG emissions (1,302 Mt CO₂), primarily from tourist transport (75%) and accommodation (21 per cent, mainly from air-conditioning and heating systems). A globally-averaged tourist journey is estimated to generate 0.25 tonnes of CO₂ (UNWTO and UNEP 2008). It is estimated that global GHG emissions from tourism to be 13 per cent higher (1,476 Mt CO₂ in 2005) (World Economic Forum (WEF 2009).

The Okavango Delta, located in north western Botswana is a key nature-based tourism destination in the country. From the 1980s, there has been an escalation of tourist facilities such as hotels, lodges, and camps in the Okavango Delta (Mbaiwa et al 2008; DEA 2008). The Okavango Delta receives a total of about 150,000 tourists annually (Mbaiwa et al. 2008). The growth not only in tourist numbers but also in facilities, infrastructure, aircraft operations, and tourism services has resulted in increased energy consumption in the Okavango Delta. The increase in tourism development in the Okavango Delta has thus raised concerns on the types and amounts of energy used in the country. Using the concept of sustainable tourism, the objective of this paper therefore, is to assess the types of energy used in lodges and camps in the Okavango Delta. The paper will also analyse policy initiatives meant to promote renewable energy within the tourism industry in the Okavango Delta.

2. Sustainable Tourism and Energy

This paper is informed by the concept of sustainable tourism. Without travel there is no tourism (Høyer, 2000). As a result, the concept of sustainable tourism is linked to a concept of sustainable mobility (Høyer, 2000). The tourism industry relies on fossil fuels and this makes tourism to be one of the industries which has an effect on climate change and global warming. About 72% of tourism's CO₂ come from transportation, 24% from accommodations, and 4% from local activities. The aviation

industry accounts for 55% of the transportation CO₂ emissions (or 40% of tourism's total) (Peeters & Dubois, 2010). Sustainable tourism therefore calls for the use of environmentally friendly energy products, regulate amounts of emissions and use of appropriate technology that promotes sustainability in the industry.

Sustainable tourism can contribute to energy and water efficiency, climate-change mitigation, waste reduction, biodiversity and cultural heritage conservation, and the strengthening of linkages with local communities (Pratt, Rivera, & Bien, 2011). As a result, making tourism businesses more sustainable will foster the industry's growth, create more and better jobs, consolidate higher investment returns, benefit local development and contribute to poverty reduction, while raising awareness and support for the sustainable use of natural resources (Pratt, Rivera, & Bien, 2011).

Sustainable tourism describes policies, practices and programmes that take into account not only the expectations of tourists regarding responsible natural resource management (demand), but also the needs of communities that support or are affected by tourism projects and the environment (supply) (ILO, 2010). In this regards, sustainable tourism thus aspires to be more energy efficient and more "climate sound" (e.g. by using renewable energy); consume less water; minimise waste; conserve biodiversity, cultural heritage and traditional values; support intercultural understanding and tolerance; and generate local income and integrate local communities with a view to improving livelihoods and reducing poverty (Pratt, Rivera, & Bien, (2011). Sustainable tourism therefore provides a framework for the management of all resources in such a way that economic, social and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes, biological diversity and life support systems (Mbaiwa et al, 2016). Wall (1997) argues that if tourism is to become sustainable, it should be economically viable, socio-culturally sensitive and environmentally friendly in destination areas. Environmentally friendliness in the tourism industry includes the use of energy types which does not degrade the environment but ensure that natural ecosystems such as the Okavango Delta to be used by future generations.

Tourism can have positive or negative impacts depending on how it is planned, developed and managed (Pratt, Rivera, & Bien, (2011). As a result, the various enabling conditions are required for transforming tourism to contribute to social and economic development within the carrying capacities of ecosystems (Pratt, Rivera, & Bien, 2011). Pratt, Rivera, & Bien argue that sustainability in tourism can be possible if the various tourism stakeholders collaborate and share knowledge and tools in order to understand the overall picture of environmental and socio-cultural impacts of tourism activities at destinations. In addition, sustainability can be achieved if there is policy coherence. In the case of tourism, government and private tourism authorities should coordinate with ministries responsible for the environment, energy, agriculture, transport, health, finance, security, and other relevant areas, as well as with local governments (Pratt, Rivera, & Bien, 2011). Policy development that spearheads sustainability means that government authorities should motivate and influence other stakeholders which include both public and private sectors to engage in behaviour that bolsters a destination's sustainability (Pratt, Rivera, & Bien, 2011).

In destination area, policymakers should set baselines and measurable targets with regard to short-, medium-, and long-term results of sustainable tourism promotion and marketing (Pratt, Rivera, & Bien, 2011). The success of tourism destinations should be evaluated not only in terms of “arrivals” but also in terms of broader economic, social and environmental drivers, as well as its impacts (Pratt, Rivera, & Bien, 2011). It is from this perspective that energy use particularly energy types and amounts as well as effects of these in tourism development in destination areas such as the Okavango Delta should be studied. The assumption is that results in this paper will provide insights into how sustainable energy in the tourism industry can be achieved in the Okavango Delta.

3. The Okavango Delta

This research was carried out in tourism camps and lodges in the Okavango Delta, located in north-western Botswana (Figure 1). The Delta is formed by the inflow of the Okavango River whose two main tributaries (the Cuito and Cubango Rivers) originate in the Angolan Highlands. The Okavango River flows across Namibia's Caprivi Strip and finally drains in north-western Botswana forming a wetland known as the Okavango Delta. The Okavango River and its Delta is characterized by large amounts of open water and grasslands, which sustain human life, and a variety of flora and fauna.

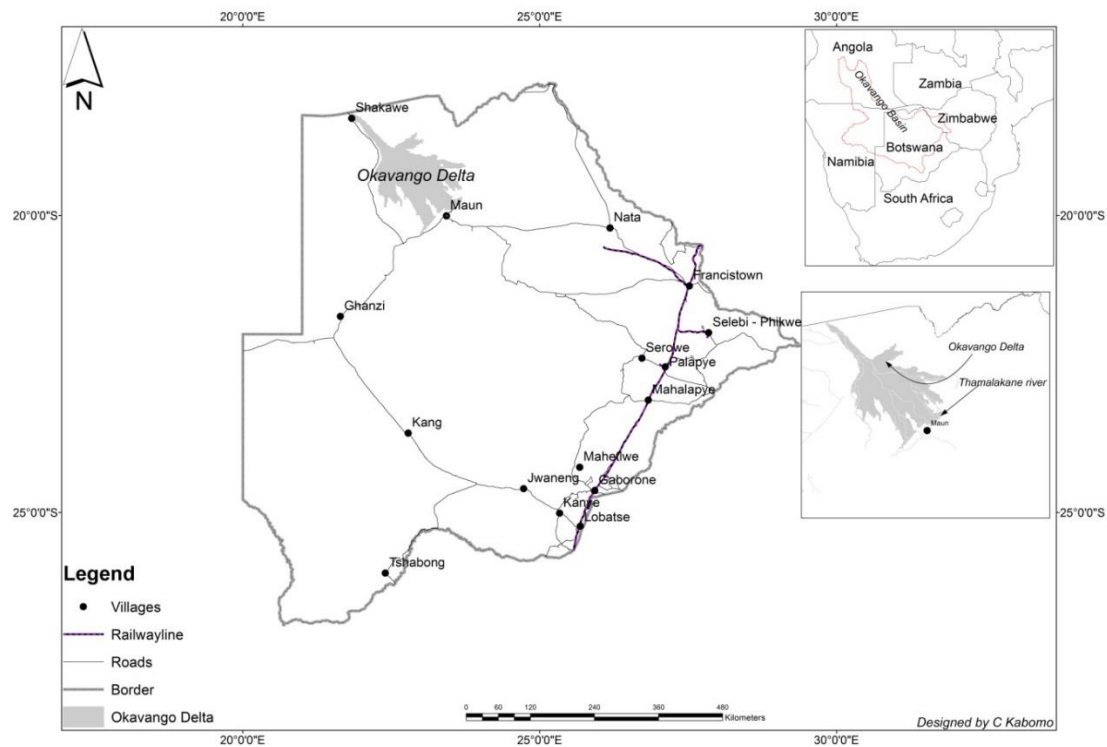


Figure 1. Map of Botswana showing the Okavango Delta.

Source: Okavango Research Institute GIS Laboratory.

The Okavango Delta was named a Wetland of International Importance and Ramsar Site in 1997 and UNESCO's 1000th World Heritage Site in 2014. Due to its rich wildlife diversity, wilderness nature, permanent water resources, rich grasslands and forests, the Okavango Delta has become a key international tourism destination in Botswana. The use of fossil fuels in lodges and camps in the Okavango Delta is one of the environmental threats that currently face the Okavango Delta. The Okavango Delta, therefore, is suitable site to analyse energy use in tourism camps and lodges so as to achieve conservation and environmental sustainability of the wetland or have fossil-free wetlands.

4. Methodology

This paper used several methods for data collection and analysis: firstly: secondary data were collected from different published and unpublished sources on tourism development and energy demand and supply in tourism lodges and camps in the Okavango Delta. Secondary data sources consisted of articles and reports on tourism development, energy demand and supply in Botswana particularly those about Okavango Delta. This includes government policy documents, consultancy reports, management plans of various camps and lodges in the Okavango Delta, community-based tourism and related cultural and wildlife-based tourism reports. Specific documents used include Botswana's Tourism Policy of 1990, Wildlife Conservation Policy of 1986, Botswana Tourism Master Plan of 2000, Community-Based Natural Resource Management (CBNRM) Policy of 2007, Okavango Delta Management Plan (ODMP) of 2008 and various management plans of various lodges and camps in the Okavango Delta, Central Statistics Office documents on energy production and distribution in Botswana with particular reference to Okavango, tourism statistics and tourism facilities in the Okavango Delta.

This study also relied on the use of information collected from secondary data sources. These include government reports, policy documents, and annual reports from the Botswana Power Corporation and the Energy Affairs Division. There was very little primary data collected in this study. This was in the form of informal interviews with government officials at the Energy Affairs Division (Ministry of Minerals, Energy and Water Affairs), Department of Electrical and Mechanical Services (Ministry of Works, Transport and Communications) and the Botswana Power Corporation in Gaborone, Botswana's capital city. The study also used synthesized data from a number studies on tourism development carried out by this author in the Okavango Delta between 1998 and 2015. Information derived from these sources includes the use of energy supply in the Okavango Delta.

Secondly, primary data were derived from questionnaires administered to tourism operators and from ongoing research by these authors in tourism development, sustainability and energy development in the Okavango Delta. As a result, unstructured interviews were conducted with key informants involved in tourism development, energy development and environmental management in the Okavango Delta. These include officials at: Okavango Wilderness Safaris, Botswana Tourism Organization, Department of Tourism, and Department of Environmental Affairs in 2015. In-depth interviews with key informants were important for gaining knowledge on energy development in the tourism industry and the potential to shift from fossil fuels to renewable energy in the Okavango Delta.

Thirdly, content or thematic analysis was used to analyse data collected. Thematic analysis involved data reduction into themes and patterns reported about energy supply and demand in tourism camps and lodges in the Okavango Delta. Leininger (1985: p. 60) argues that in thematic analysis, themes are identified by “bringing together components or fragments of ideas or experiences, which often are meaningless when viewed alone”. The themes that emerge from the informants stories are pieced together to form a compressive picture of their collective experience (Aronson, 1994). Qualitative data collected from secondary sources about energy supply and demand in the Okavango Delta were summarized into specific themes and patterns. This provided an analysis about the sustainability of energy development in tourism camps and lodges. Finally, quantitative data collected was analyzed and it involved the production and interpretation of frequencies and tables that describe ecotourism development in Botswana.

5. Results & Discussion

5.1 *Overview of Energy Supply in Rural Ngamiland District*

The Okavango Delta is located in a district or province known as Ngamiland District. Ngamiland District has a total population of 152 284 people with an estimated inter-censal growth rate of about 2% for the period 2001 to 2011 (CSO, 2011). The majority of these people have no modern energy supply in their homes and use fuel wood as the main energy source. That is, Ngamiland District is one of the nine districts in Botswana and is classified as a rural district where the energy profile is such that the use of modern energy sources is very low except in commercial areas such as the tourism industry. Botswana’s energy profile is similar to that of most developing countries where the dominant energy source is fuel wood which is mostly used in rural areas. For example, the major source of energy supply in Botswana is dominated by fuelwood which contributed 34% of the total primary energy supplied, followed by coal at 31%, petroleum 30%, electricity 5% and solar energy which contributes insignificant amount of less than 0.2% (MMEWR, 2015). While the use of solar energy is low in Botswana, the country has abundant solar energy resources with more than 3,200 sunshine hours and average radiation of 21 MJ/M² per day (Mosimanyana et al 1995). This places Botswana among the countries with the best solar energy regimes, which is suitable for providing rural areas particularly the Okavango Delta with solar energy.

5.2 *Energy Supply in Lodges in the Panhandle Area*

Lodges and hotels located in the inlet of the Okavango Delta also known as the panhandle area of the Okavango Delta such as Drowsky Cabins and Shakawe River Lodge are connected to the national grid which is burning fossil fuels in the production of electricity. The Panhandle is the upper part of the Okavango River. The Okavango River Delta is conventionally divided into four water and land categories: the Panhandle, upstream permanent swamps, downstream seasonal flood plains, and large islands and sandveld tongues (DEA, 2008). DEA notes that the upstream Delta is characterized by the main Okavango River flowing through extensive papyrus swamps, bifurcating into distributary channels which convey the flow on to extensive perennial flood plains. As a result, lodges and camps in the panhandle are located along the river. Many villages in the panhandle such as Shakawe, Gumare and Seronga are located along the river. These villages are connected to national electric grid and use electricity generated from the burning of fossil fuels. That lodges and camps have opted for connection

to the national grid and that use fossil fuels means that these lodges are having a contribution to the carbon emissions, climate change and global warming.

The case of lodges and camps in the panhandle being connected to the national electric grid and using electricity generated from fossil fuels is an example of the failure of the Botswana Energy Policy of 1997 which aimed at rural electrification through photovoltaic (PV) electrification. Botswana's energy policy notes that solar energy mainly for water heating and remote area electricity generation has promise for application in Botswana with its good isolation and long sunshine (MFDP, 1997). As a result, government aims at encouraging sustainable PV electrification programmes of which attention is given to the enforcement of standards, increased technical training, effective maintenance arrangements, sustainable financing mechanisms, as well as information dissemination to relevant groups.

The PV rural electrification programme is expected to compliment the grid system especially in rural areas where renewable energy offers the best opportunity (Zhou et al 1999). That is, the PV system is expected to be the main source of energy in areas where it is not considered economical viable to provide electricity through the grid system. Shakawe, Gumare and Seronga are remote villages which could easily benefit from PV electrification. However, the grid and the PV rural electrification system appear to be competing than complementing each other (UNICO International Corporation 2001). The results of this situation have been the low rate of rural electrification by both programmes. In addition, government policy appear to be narrow in the promotion of renewable energy in that it concentrates on solar energy without particular attention to other potential renewable energy sources such as wind and biogas which also have potential in Botswana especially in rural areas. The rural villages of Shakawe, Gumare and Seronga are therefore not connected to PV electrification and this has resulted in lodges and camps located along the Okavango River in this area using electricity generated from fossil fuels.

5.3 *Fossil Fuels in Lodges and Camps*

Lodges and camps in the Okavango Delta are often not connected to the national electricity grid hence rely on fossil fuels to meet their energy demands. Fossil fuels which lodges and camps use in the Delta include petroleum products such as diesel, oil, paraffin, paint and aeroplane gasoline (Mbaiwa et al, 2016). The majority of lodges and camps in the Okavango Delta use diesel for various purposes. For example, diesel is burnt down in diesel generators to produce electricity. Electricity from diesel generators is used for cooling, water heating, lighting and for storage of food in deep freezers and fridges. In addition, GISPlan (2013) notes that most of the fuel, especially diesel is used for heavy machinery for maintenance of airstrips, trial system and for the game drives. Lodges and camps in the Okavango Delta are located in isolated and scattered locations where accessibility by roads is generally difficult. In this regard, air transport is mostly used. As a result, a great deal of jet fuel is also used for air transfers of tourist from Maun Airport to various parts of the Okavango Delta due to the accessibility issues.

Each of the lodges and camps in the Okavango Delta transports a significant amount of petroleum products into the Okavango Delta on monthly basis. Table 1 shows that a total of 1,316 litres of oil,

9,600 litres of petrol and 21,400 litres of diesel are transported on monthly basis into the Okavango Delta (Aqualogic, 2008). The diesel is burnt to produce electricity and provide energy for their tourism facilities. Paraffin, paint and wood preservatives (wood guard, timber varnish) are used in relatively small quantities.

Table 1: Quantities of Petroleum Products in the Okavango Delta

Usage rate	Hazardous Substances brought into the delta						
	Oil (L/month)	Petrol (L/month)	Diesel (L/month)	Paraffin (L/month)	Paint (L/year)	Wood preservatives (L/year)	Used oil (L/month)
Total	1316	9600	21 400	300	180	300	1356
Average per establishment	73	738	1338	50	20	50	75

Source: Aqualogic (2008)

The main modes of transporting these substances into the delta are road, air and boat. A total of 78% of the tourism establishments use professional transport companies particularly a company known as Pony Transport to transport the substances into the sites. The remaining 22% transport fuel on their own into the delta. Pony Transport can transport at most 8,000 litres of fuel in one trip. As such, the likely quantity of fuel spill is 8,000 litres (Aqualogic, 2008). Table 2 shows the amount of petroleum products brought into the Okavango Delta each month to meet energy demands of various tourism lodges and camps. The main modes of transporting these substances into the delta are road, air and boat. A large quantity of fuel (80%) is transported by road (Aqualogic, 2008).

Table 2: Quantities of fuel by mode by of transportation

Mode of transportation	Oil (L/month)	Petrol (L/month)	Diesel (L/month)	Total (L/month)	Proportion (%)
Road	1052.8	7680	17120	25852.8	80
Air	157.92	1152	2568	3877.92	12
Boat	105.28	768	1712	2585.28	8
Totals	1316	9600	21400	32316	100

Source: Aqualogic (2008)

There are various containment methods are used to bring the oil, petrol and diesel to different sites in the Okavango Delta. For example, 23,267.52 litres/month (78.26%) is transported in drums and 6,463.2 litres/month (21.74%) transported in partitioned tanks (Aqualogic, 2008). Aqualogic notes that paraffin, paints, wood preservatives and some oil are usually brought into establishments in original containers of various volumes. Oil is usually stored in drums and original containers. A total of approximately 19,840 litres/month (64%) of petrol and diesel are stored in drums, 8,990 litres/month (29%) in underground tanks with pumps and 2,170 litres/month (7%) in elevated fuel tanks. Paraffin, paints and wood preservatives are usually stored in original containers.

Some tourism establishments use underground storage with pump while others use elevated tanks. Storage of petroleum products in most of the lodges and camps in the Okavango Delta is not done to the recommended storage standards (ODMP 2008; GISPlan 2013). Aqualogic (2008) notes that a total of about 19,840 litres/month (64%) of petrol and diesel are stored in drums, 8,990 litres/month (29%) in underground tanks with pumps and 2,170 litres/month (7%) in elevated fuel tanks. Paraffin, paints and wood preservatives are usually stored in original containers. About 70% of permanent lodges/camps service their vehicles on site, hence generating used oil. This therefore provides insights into the amount of petroleum products which are transported into the Okavango Delta in a month and how such fossil fuels are stored.

4.2 *Solar Energy in Lodges/Camps in the Okavango Delta*

Renewable energy used in the Okavango Delta include solar and fuel wood. Wood fuel discussed in the next section of this paper is used in many lodges and camps for bonfires and at times for heating water. Solar energy is becoming prominent with some of the lodges and camps in the Okavango Delta. It is suitable for cooking, lighting, water heating, space heating and ironing. However, the intake and use of solar energy is very low as the majority (over 80%) of the tourism facilities rely on the use of fossil fuels.

Although the use of solar energy is low in the Okavango Delta and in Botswana as a whole, the country has abundant solar energy resources with more than 3,200 sunshine hours and average radiation of 21 MJ/M² per day (Mosimanyana et al 1995). This means solar energy is an available natural resource which is not efficiently used in the Botswana. However, some of the tourism are responding to the global call for promoting green tourism, this is a tourism industry which use and promotes renewable energy sources and its environmentally friendly. The use of renewable energy or going green in tourism has become a marketing strategy which companies use to sell their tourism products. The Okavango Delta being a natural ecosystem has become an appropriate destination for some companies to market themselves and introduce solar energy as well. Some of the solar initiatives from selected tourism companies are discussed below:

a) Solar Energy Use in Loges/Camps owned by Okavango Wilderness Safaris

The Okavango Wilderness Safaris (OWS) owns and operates 22 lodges/hotels in the Okavango Delta. OWS has adopted a shift in its policy to move away from the use of fossil fuels to solar energy in all its lodges and camps. The company is doing this in phases over the next few years. Informal interviews with the Environmental Officer at Okavango Wilderness Safaris indicate that a total of 10 lodges have already use 100% solar to meet their energy demands. The company acknowledges that its lodges are situated in remote areas and generally off-grid hence required generating electricity for their lodges and camps (Wilderness Holdings, 2015). Wilderness Holdings further notes that historically, electricity was provided to the lodges through diesel-fuelled generators. OWS notes that its main goal is to reduce dependence on fossil fuels with the aim of eventually being carbon neutral in the tourism business. Wilderness Holdings notes that it's currently converting camps to alternate energy sources such as solar power. Wilderness Holdings (2015) notes:

In 2015, our solar power investment grew to the point where we can generate 517 kW from plants in 16 camps, of which nine are 100% solar powered and four have hybrid systems which use a combination of solar power and generators. A further 12 camps operate off smaller solar systems that power each guest unit independently, leaving the generator to power only the main area.... 22 camps make use of inverter-battery systems that enable them to reduce generator running times from 24 hours to an average of just nine hours daily. The result is that we consumed 214 239 GJ of energy, a 12% decrease from the 244 614 GJ consumed in 2012. Over the same period, our carbon emissions have reduced by 13% from 17 412 tonnes CO₂e to 15 135 tonnes CO₂e (Wilderness Holdings, 2015: 14).

The use of solar energy in the Okavango Delta has proved to have environmental protection of some carbon emissions for companies that use this technology. For example, Wilderness Holdings (2015) notes that between 2012 and 2015, it managed to reduce carbon emissions by 16% from 0.097 to 0.081 tonnes CO₂e per bednight. Wilderness Holdings provides a case study upon which petroleum products can be reduced or replaced in lodges and camps in the Okavango Delta. In addition, there are also financial savings which companies make when using solar energy. For example, Okavango Wilderness Safaris notes that its energy budget made financial savings amounting to a total of P3, 875,842 (USD 387, 584) in a year in five (5) camps which shifted from the use of fossil fuels to solar energy (Wilderness Holdings, 2015). This therefore shows that the use of solar energy is cannot only be an environmental friendly strategy for tourism development but also a financial sustainability approach for tourism companies operating in the Okavango Delta.

b) Solar Energy Use in Loges/Camps in Concession Area NG/31

The use of solar energy has been adopted by two tourism companies operating in a tourism concession area known NG/31. This concession area covers a total area of 225 square kilometers. In this concession area, there are two lodges known as Sandibe Safari Lodge and Chitabe Camps. Sandibe Safari Lodge

uses a diesel generator for almost 80% of time and an inverter system for the rest of the time. On the other hand, in Chitabe Main and Chitabe Lediba Camps currently use solar energy for two thirds of the day hours in their facility and their generator provides energy for the rest of 7 hours per day. The ultimate goal of Chitabe Camps is to have solar energy running for 24 hours in their facilities. The management Plan for Controlled Hunting Area NG/31 indicates that at least 70% of the energy requirements for all lodges and camps would be using renewable energy (mainly solar energy) by 2017 (GISPlan, 2012). The case of N/31 demonstrates the fact that energy supply in the Okavango Delta is mostly from petroleum products such as diesel and petrol. However, the use of solar energy is possible and can serve as an alternative in these remote parts of the country.

c) Solar Energy Use in Concession Area NG/21

In another concession area known as NG/21 which covers a total of 230.54 square kilometres there are three lodges located within 8 km of each other. These lodges are: Camp Okavango, Xugana Lodge and Shinde Camps. All lodges and camps in NG/21 are using the following forms of energy: fuelwood used for bonfires, diesel generators to produce electricity for lighting and refrigeration; battery charging for lighting especially at night when the generator is not in switched on; and propane gas for cooking in kitchens. Solar energy is currently being used to heat water at Xugana Lodge (for guests) and at Shinde Camps (at staff village). At Camp Okavango, energy or Generator power (AC 220V) is available during the day and evening. Video batteries can be recharged. Rooms are equipped with a 220volt AC plug for hairdryers and 12volt DC lighting for night time use, after the generator has been switched off. At Xugana Camp, Generator power (AC 220V) is available during the day and evening. 12volt DC lighting is supplied for nighttime use, after the generator has been switched off. Video batteries can be recharged – AC 220 volts. The same amount of energy is generated at Xugana and Footsteps Across the Delta to provide the camps with the necessary energy. Given the “ever growing” demand to reduce carbon emissions (even by this, small-scale facilities), there will be a need to substitute the existing diesel, generator-based power supply with solar solution. This therefore suggests that much needs to be done in order to introduce renewable energy resources for a fossil free Okavango Delta.

The case of NG/31 and NG/21 demonstrates that the uptake of solar energy is currently still very low in the Okavango Delta. For instance, in Controlled Hunting Area NG/21, solar energy was only used to heat water at the two camps of Xugana and Shinde, in 2013, whereas other lodges and camps used diesel generated electricity for lighting and refrigeration, firewood for bonfires and batteries for lighting when generators were off late at night. Similarly, in 2012, only two lodges of Moremi Crossing and Gunn’s Bush Camp used solar energy in Controlled Hunting Area NG/27 (GIS Plan 2012). The used of solar energy suggests that solar energy might be a feasible renewable energy source in camps and lodges in the Okavango Delta.

4.4 *Environmental Threats Caused by Type of Energy Used*

a) *Environmental Threats of Using Fossil Fuels*

Fossil fuels have the potential of being an environmental hazard if not handled appropriately using appropriate storage and transportation facilities. For example, a large quantity of fuel (80%) is transported by road, with the probability of a large land spillage in case of an accident (Aqualogic, 2008). Generally, different surface routes are used to transport the substances to sites in the Okavango Delta. The routes have a wide coverage, reaching into the centre of the delta. This means that any substantive spillage of hazardous substances could have a significant impact on the delta environment. Transportation of fuel, particularly in difficult roads such as the ones in the Okavango delta, has the potential to result in leakages and spills. Apart from transportation, vehicle service areas and/or leaking storage facilities have the potential to contaminate the surrounding environment. In order to minimize potential environmental harm, it is important that spills are contained and areas affected be treated (Aqualogic, 2008).

Oil spillages into water and the soil in the Okavango Delta occur during the servicing of vehicles. Aquaogic (2008) notes that a total of 70% of permanent lodges/camps indicated that they service their vehicles on site, thereby generating used oil. Houseboats are serviced on site because of their big size and there are no precautions undertaken to safeguard possible spillage of oil. Servicing of vehicles also generates solid waste in the form of oil filters. The amount of used lubricating oil (engine and gearbox) generated on a monthly basis in lodges and camps varied from approximately 5 litres to 800 litres. The used oil was stored onsite in 20litre or 200litre containers or large overhead tanks until transport was available to take it to Maun for bulk storage and transportation to South Africa for recycling. It also established that, while there appears to be some control in storing the used oil, sand containment areas where used oil was stored, appeared saturated and substantial areas of ground at these sites was contaminated with oil and fuel spillage (Aqualogic, 2008). Studies (e.g. DEA 2008; GISPlan, 2012) have shown that the management of these petroleum products in some of the lodges and camps is poor in that spillages are reported to be common. Oil spillages to the ground possess serious environmental challenges to the fragile Okavango Delta wetland ecosystem. This therefore shows that fossil fuels are a threat to the environment in the Okavango Delta.

4.5 *Policy and Energy Use in Remote Locations*

Environmental issues since the evidence of first green house effect have received considerable interest of researchers and policy makers of the world (Tiwari et al, 2013). The tourism industry is reported to be an increasingly significant contributor to greenhouse gas (GHG) emissions (Gössling et al, 2007). Gössling et al note that emissions growth in the sector is in substantial conflict with global climate policy goals that seek to mitigate climate change through significant emission reductions. As a result, there is need for policy change that aim at the reduction of green house gases and climate change to promote the use of renewable energy. This paper has shown that tourist camps and lodges in the

Okavango Delta mostly use fossil fuels than renewable energy. However, the Botswana Government has adopted the Energy Policy of 2015 which aims at promoting the use of renewable energy in the country. The Energy Policy objectives of the energy policy are spelt out and one of them indicate commitment to energy sources which are environmentally friendly, it notes: “minimize energy related impacts on environment” (MMEWR, 2015:2-3): District-level policies also determine the adoption of renewable energy technologies at the local level. For instance, the Ngamiland District Development Plan 7 (2009-2016), which covers the Okavango Delta, states that the utilisation of renewable energy sources will be promoted in the plan period. The technologies mentioned include solar photovoltaic electrification systems for lighting and solar thermal energy systems for water heating. Although the plan does not mention its vision for the provision of energy in remote areas of the Okavango Delta, where there are tourist camps and lodges, the understanding is that renewable energy in the district is promoted for adoption.

To achieve sustainability in energy use in the tourism industry and promote green tourism, there is need for policy to make provision for a code of conduct for tourists and hosts and this code should encourage use of renewable energies and reduced negative impacts on the environment (Marunda et al, 2013). Green tourism which in essence is a form of sustainable tourism which calls for a clean healthy environment to put the tourism and hospitality industry on the path to sustainability (Marunda et al, 2013). In Botswana, the Botswana Tourism Organisation (BTO) adopted the Botswana Ecotourism Certification Standards in 2010. These Standards promotes the use of renewable energy in lodges and camps in the Okavango Delta. The Botswana Tourism Organisation (BTO) encourages ecotourism operators to use energy efficiently in their camps and lodges. The BTO manual on Ecotourism Best Practices requires ecotourism operators in the Okavango Delta to prepare energy conservation plans. These conservation plans are supposed to state the conservation measures to be adopted, including the installation of compact florescent lights and use low energy appliances (Botswana Tourism Board, 2010). The Environmental Officer at BTO, Mr Richard Malesu during an informal interview indicated that the Botswana Government supports a shift from the use of fossil fuels to renewable energy. Mr Malesu noted:

“Botswana Tourism Organisation encourages the use of renewable energy in tourism lodges and camps in the Okavango Delta as illustrated as a component of Botswana Ecotourism Certification Standards for Accommodations and Ecotours. It has also become a requirement for lease renewal for concession areas to illustrate commitment towards introduction and implementing of use of renewable energy to promote environmental best management practices and to eliminate pollution and soil contamination from fuel/oil or fossil fuel at large and emission of carbon through the carbon offset or carbon sequestration on the sensitive ecosystem of the Okavango Delta as a Ramsar Site and World Heritage Site.

The challenge with Botswana Ecotourism Certification Standards is that they are voluntary and companies may opt not to be using them (Mbaiwa et al, 2011). This information was also collaborated the Environmental Office at BTO during informal interviews. The BTO Officer noted that renewable energy is: “illustrated as a component of Botswana Ecotourism Certification Standards for Accommodations and Ecotours. Even if this is a voluntary exercise, there has been a significant growth of tourism facilities which participates in this noble exercise” (Richard Malesu, personal

communication, November 2015). The challenge is that if standards which prescribe how renewable energy is to be adopted in the tourism industry are voluntary, some of the companies might opt to continue the use of fossil fuels which in reality is not environmentally friendly but harmful to fragile ecosystems like the Okavango Delta. Mbaiwa et al (2011) note that during the consultation workshops in the precertification stage with tourism stakeholders, representatives of companies operating lodges in environmental sensitive areas argued that standards should be made compulsory instead of voluntary as is the case at present. Despite the limitations posed by standards and a specific policy on renewable energy, results indicate that government is partially committed to the fact that the tourism industry in the Okavango Delta should embrace a shift from fossil fuels to renewable energy sources. In addition to energy policy and the various management plans for the various concession areas in the Okavango Delta, the tourism industry is thus obliged to use renewable energy in their tourism facilities.

The Botswana Government has regulations governing the use of hazardous substances in the Okavango Delta. For example, Botswana's Waste Management Strategy (WMS) of 2006 notes that the amount of used lubricating oil (engine and gearbox) generated on a monthly basis in lodges and camps in the Okavango Delta varies from approximately 5 liters to 800 liters. Accordingly to WMS requirements, used oil or petroleum products is to be stored on site in 20liter or 200liter containers or large overhead tanks until transport is available to take it to Maun for bulk storage and transportation to South Africa for recycling. In all the lodges and camps in various concession areas in the Okavango Delta, petroleum products like used oil from the camps are transported to Maun through hired companies. In this regard, much of the petroleum waste and hazardous materials are disposed in Maun.

Fuel storage facilities in all camps/lodges in the Okavango Delta have bund walls to ensure that spills and leaks are contained. The storage facilities have plastic ground sheets covered with sand so that spills can be collected and shipped out if necessary. There is, however, poor handling of some of the petroleum products in some of the camps and lodges such as Xugana Island Lodge in NG/21. The concrete floors under the oil tanks are not constructed to the required standards, thus posing a risk for oil spillages on the ground (a phenomenon that is not desirable for difficult sites or environmental sensitive sites). With regard to this, proper oil and fuel storage management standards will also need to be recognized and enforced especially by tourism operators. Results in this research indicate that even though there are regulations on how fossil fuels are to be handled in the Okavango Delta to avoid environmental effects, most of the operators do not observe these regulations, making it necessary to adopt a policy approach which aim at shifting from the use of fossil fuels to renewable energy sources such as solar which are generally clean and environmental friendly.

5. Conclusion

This paper has shown that there are four main types of energy sources used in lodges and camps in the Okavango Delta, these are: a) fossil fuels made from burning of coal-this is used by lodges and camps in the panhandle which are connected to the national electric grid; b) fossil fuels especially petroleum products; c) fuel wood mostly used for born fires; d) solar energy which is relatively new in the Okavango Delta. However, the proliferation of lodges and camps in the inner parts of the Okavango

Delta introduced and increased use fossil fuels particularly petroleum products for energy supply. Over 80% of the lodges and camps in the Okavango Delta use fossil fuels for their energy supply (Aqualogic, 2008). Petroleum products like diesel are used to produce electricity. Electricity from diesel generators is used for cooling, water heating, lighting and for storage of food in deep freezers and fridges. The use of fossil fuels has proved not to be environmentally friendly and contribute to climate change and environmental degradation in the Okavango Delta. Therefore, there is need to shift from the use of fossil fuels to renewable energy in order to create sustainability and a fossil free wetland in the Okavango Delta.

Solar and fuel wood are the only renewable energy sources used in tourist camps and lodges in the Okavango Delta largely used fossil fuels. However, the use of renewable energy such as fuel wood and solar is limited. It is from this perspective that efforts research should be carried out in order to provide insights into how renewable energy sources can be made the main source of energy in tourist camps and lodges in the Okavango Delta. There is therefore need for policy which encourages a shift from fossil fuels to renewable energy especially solar energy is a feasible option for the Okavango Delta. The use of solar energy is environmentally friendly and promotes the ideals of sustainable tourism development in the Okavango Delta. In addition, tourism operators and companies opting for the use of solar energy save financial costs since running costs of solar energy are far cheaper than used fossil fuels. This approach has the potential of achieving sustainability in the Okavango Delta and a fossil free wetland.

Finally, in the tourism sector, policies that promote renewable energy should aim at reducing the removal of biodiversity, policies should ensure the use of renewable energy and promote the preservation and protection of the environment (Marunda et al, 2013). Marunda et al note that such policies should aim at promoting the development and dissemination of renewable energy tools and materials within the tourism sector. In addition, tourism operations and hotels management actions and investment decisions should include the use of energy; and, that policy should raise awareness of tour operators, transport providers and hotel managers, decision-makers, staff and consumers of the benefits of using renewable energies. Policy changes that promote a sustainable tourism industry will also require changes in technological innovation and behavioural changes especially travel patterns of human beings. Gössling et al (2007) argue that there is an opportunity to accommodate a greater number of people travelling in a declining emissions budget for tourism, by combining technological innovation and behavioural change, and induced by appropriate government intervention.

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Sustainable Renewable Energy Mini-grids for Energy Access: Economic and Social Benefits of Mini-grid Systems

Paul Chisale¹, Samuel John², Andrew Zulu³

Abstract

Sub-Sahara African region has one of the highest solar irradiation levels; approximately 6kWh/m². Yet, most of the people who live in rural areas, approx. 64%, are energy-poor. Mini-grid systems provide alternative means to access clean energy, especially for rural communities, since they can operate in stand-alone and central grid modes. Despite the numerous advantages of solar photo-voltaic (mini grids) systems, there are also several challenges that inhibit successful deployment of renewable energy mini---grids in order to ensure their long---term sustainability. These challenges range from economic, financial, technical, policy and legal impediments. The social and economic benefits that come along with renewable energy mini---grids deployments at local and national level are key ingredients of the country Human Development Index (HDI) and these are discussed in the session.

Keywords: HDI, laws, mini---grids, policy, sustainability, sustainability

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1. Introduction

According to the International Energy Agency, the average electrification rate (in terms of population), across all the developing countries in the world, is 76% with approximately 92% in urban areas and around 64% in rural areas [1]. The social economic benefits of electricity access are well known. For instance, longer study hours for children, a reduction in domestic work burden on women by providing access to renewable energy appliances, increased economic productivity, entertainment and access to enhanced healthcare, government and other services etc. [2].

Photovoltaic as a renewable energy system, i.e. mini grid systems, present a number of advantages for provision of energy. Sub-Sahara in particular has high solar irradiation (6kWh/m^2) [3] which makes photovoltaic systems an efficient and cost-effective way of delivering energy to meet basic needs, when compared to the poor quality of energy provided by “traditional” sources (i.e. candles, biomass, paraffin lamps and stoves) or to the high operating costs of electricity sources, like running a diesel generator in remote areas. Even in areas near the grid, solar systems could, for some users, be better adapted to their low energy consumption. Furthermore, the reliability of solar energy systems, with proper maintenance, is far higher than that of a diesel generator due to the lack of dependence on the supply of mechanical parts and fluctuating prices of diesel fuel. Secondly, investments in generating energy with solar PV systems can be configured to the demand. Thirdly, PV systems can be deployed, in remote locations, where electricity can be delivered to end-users directly in the absence of a grid. This is because mini---grids are defined as one or more local generation units supplying electricity to domestic, commercial, or institutional consumers over a local distribution grid. They can operate in a standalone mode and can also interconnect with the central grids when available.

Mini---grids systems have distinct multiple advantages over central grids and other decentralized energy distribution systems in providing access to reliable and affordable energy [4]. For instance:

- i. PV mini---grids can be less expensive due to lower capital cost of infrastructure (depending on distance) and lower cost of operation by avoiding transmission and distribution losses compared to central grid extension.
- ii. Power shortages, from the central grid, especially in rural areas, may not be reliable. In such cases, RE mini---grids can be designed and operated effectively to off-set power shortages. Hence, would turn out more reliable than the central grid in providing electricity access and therefore, ensuring local energy security.
- iii. Mini---grid developers have the potential to access capital beyond the traditional power sector, and Mini---grid may be able to provide quicker access to electricity than central grid extension that may be prone to bureaucratic hurdles and slow implementation processes.
- iv. Like other decentralized energy options like solar home lighting systems and off---grid lighting products, mini---grids (depending on their size) can provide electricity to not only residential loads for lighting and phone charging, but also to commercial loads like mills and oil presses.

- v. RE mini-grid developers have strong incentives to pursue demand-side management, to keep capital cost of generation equipment low.
- vi. Development and operation of mini-grids can create local jobs.
- vii. Despite the advantages of solar photovoltaics (mini grids) systems there are also several challenges that inhibit successful deploying RE mini-grids in order to ensure their long-term sustainability. These challenges include, among others:
- viii. High up-front capital costs unaffordable for the majority of end-users living in the rural areas of developing countries;
- ix. Low capacity factors;
- x. Often higher residential tariffs compared to central grid consumers;
- xi. Insufficient financing support and investment;
- xii. Technology failures;
- xiii. Lack of effective institutional arrangements to ensure reliable and efficient operation and maintenance over time;
- xiv. Lack of mechanisms to address grievances; and
- xv. Uncertainty in the face of possible future central grid extension.
- xvi. Well-designed policies and appropriate institutional arrangements along with effective financing mechanisms can address many of these challenges and lead to the successful and sustainable deployment of renewable energy mini-grids.

2. ELEMENTS OF PV GRID SUSTAINABILITY

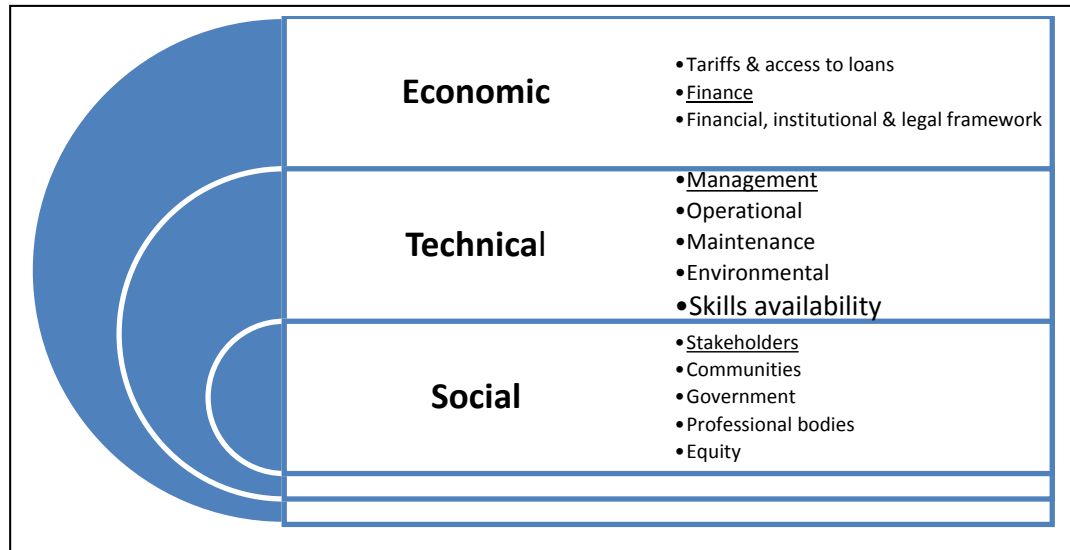
First, a set of elements that define sustainability (Figure 1), from experience point of view, indicates that the integration of mini-grid in development of the energy sector help to ensure that mini-grids play a critical successful role in the long-term provision of electricity and access. The elements of sustainability, shown in Figure 1, are essential in formulating policies and addressing the concerns of all stakeholders, including mini-grid consumers (communities), project developers, government, utilities and financiers. The elements of sustainability of PV grids are economic, technical, social, environmental and scalability.

Economic sustainability relates to affordable tariffs for consumers while ensuring long term financial viability of the PV grids, with adequate revenue to cover operational expenses, liabilities, and profit.

Technical sustainability ensures reliable operation of the mini-grid system over its expected lifetime with minimal downtime.

Social sustainability includes the level of community involvement and how well the policy ensures that the mini-grid system caters to the local context.

Inherently scalability is incorporated to include a dynamic component in the evaluation, and to assess the ability of the policy to affect growth of the mini-grid.



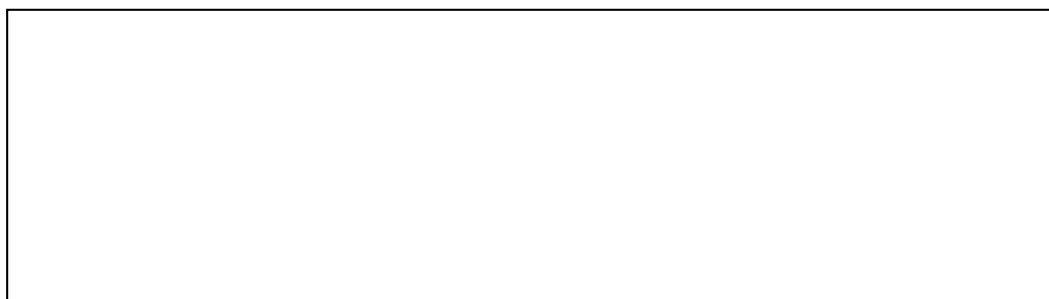
Sustainability

Figure 1: Elements of sustainability for PV Grid System

An environmental perspective is applied to insure future energy generations are not made worse off by present electrification efforts and resources are not depleted.

Finally, an equity element must be in place to assess the distributional aspects of a policy and how well the policy performs to ensure universal access to electricity. However, Demand-side management (DSM) is also crucial. DSM refers to a mix of incentives and disincentives that influence the amount and timing of energy use in order to better utilize the available resources.

The elements, Figure 1, are generally tied to large scale and medium scale PV grid systems. In the case of community owned PV systems the owner and operator of the system is the community. Community based systems tend to be more common in developing countries where the private sector or utilities remain limited. The community executes maintenance, tariff collection, and management services as shown in Figure 2.



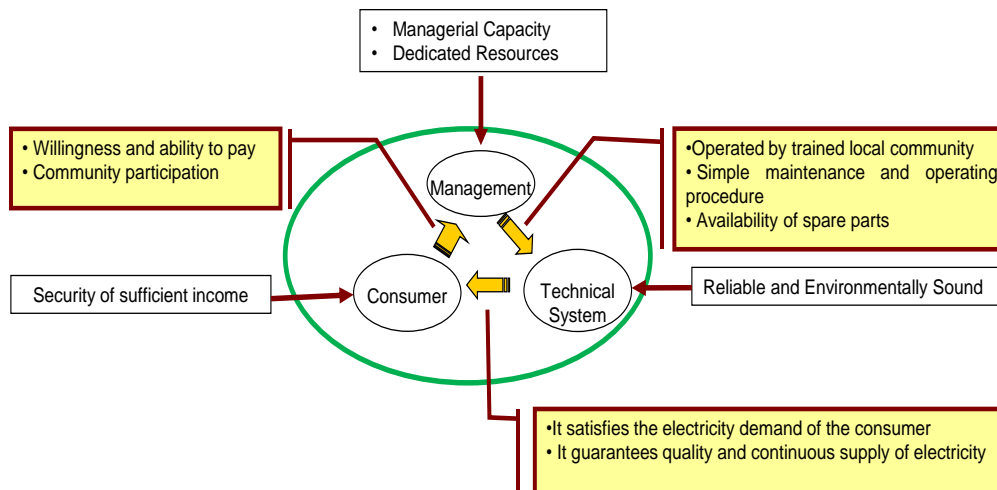


Figure 2: Elements of sustainability for Small PV Grid System

Communities may lack technical and business skills (e.g. design and installation; tariff setting), leading to higher costs and the management of systems needs to be well articulated bearing in mind policy issues.

3. Policy Issues

The three broad aspects of a comprehensive RE mini-grid policy are: 1) institutional structure and governance, 2) technical standards, and 3) financial incentives, and tariffs. The financial incentives and tariffs is simply a matter of Demand-side management (DSM) taking into account the roles and activities by different stakeholders.

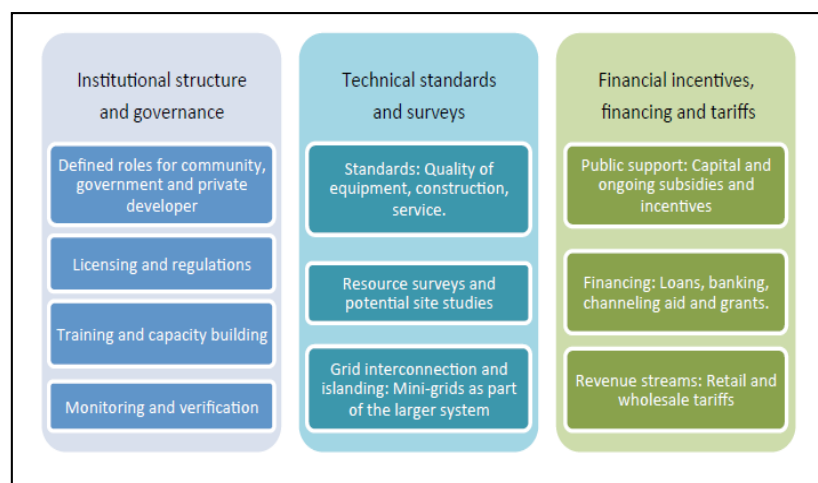


Figure 3: Aspects of a comprehensive RE mini-grid policy

3.1 Roles in Mini---Grids

Generally, key stakeholders and role players, to be involved min grid development, are the government, private enterprises, financing institutions, NGOs, consumers, and the community. The roles and activities by different stakeholders depend on the cultural context, legal framework, economic viability, and institutional arrangements in a particular country (Fig. 3). These roles and activities (Table 1) include among others: owning, building, operating, maintaining and paying for a mini---grid systems. Community involvement is a key component of successful mini---grids [5], though it might take many different forms. Community participation at least in high---level decision---making processes before and during system operation is vital to the sustainability of a mini---grid system. Appropriate institutional arrangements, as a precursor to providing energy services, effective deployment and subsequently, operation, management, and maintenance of RE mini---grids, are critical for scaling up the development and deployment of mini---grids. The role, of putting institutional measures in place, is mostly executed by governments. This is because there is a set of larger responsibilities that governments ought to undertake, through specific institutions including defining the national energy policy, electrification goals, setting rural electrification strategies and providing financial incentives for mini---grid developments and operations.

In some countries, the governments (or state---owned utility) are explicitly involved in building and operating the mini---girds, while in others governments play facilitators' and regulatory roles, while letting private sector and the communities to be in charge. Communities ought to be endowed with functional roles that include commercial and technical operational of the system, tariff determination, penalties definition, and monitoring and verification of activities.

Table 1: Community Participation

What?	Activities	Skills/Items Needed	Timescale
Management	<ul style="list-style-type: none"> ❖ Checking the system functionality; [1] ❖ Energy Management; [3] ❖ Reading electricity usage; [4] ❖ Comparison with expected results [4] 	<ul style="list-style-type: none"> ❖ Communication [1] ❖ Basic system knowledge; [2] ❖ Manual for emergencies [4], [1] out sourced* 	Daily
Cleaning & Maintenance System	<ul style="list-style-type: none"> ❖ Top up of battery; [1] ❖ Cleaning of solar panel; [3] ❖ Checking of wiring; [3] ❖ Performance of routine maintenance [1] out sourced* 	<ul style="list-style-type: none"> ❖ General cleaning skills; [4] ❖ Labor to clean; ❖ Diligence [4], [1] out sourced* 	Monthly
Monitoring	<ul style="list-style-type: none"> ❖ Checking monitoring logs; [4], [1] out sourced* ❖ Serve data on saver & backups [3] 	<ul style="list-style-type: none"> ❖ Computer Skills [1] out sourced* 	Monthly

Scale: 1 Excellent; 2. Good; 3. Average, and 4. Poor

Table 1 illustrates community participation, activities and skills required for a sustainable the mini grid at Gobabeb in Namibia.

However, there are many important lessons and strategies to balance the potentially competing goals of energy service and economic viability to cater for high---value customers [6], and how to facilitate community involvement in the design and operation of mini---grids. Most often strategies exist to meet, or marry, these goals. For instance, failing to include local leaders has been perceived as a threat to their position in the villages, resulting in improper maintenance and even the disconnection of the system. Also various metrics for community---wide market, appliances and polices are cardinal in assessing the success or failure, to meet the set goals, of specific mini---grid projects (Fig 3).

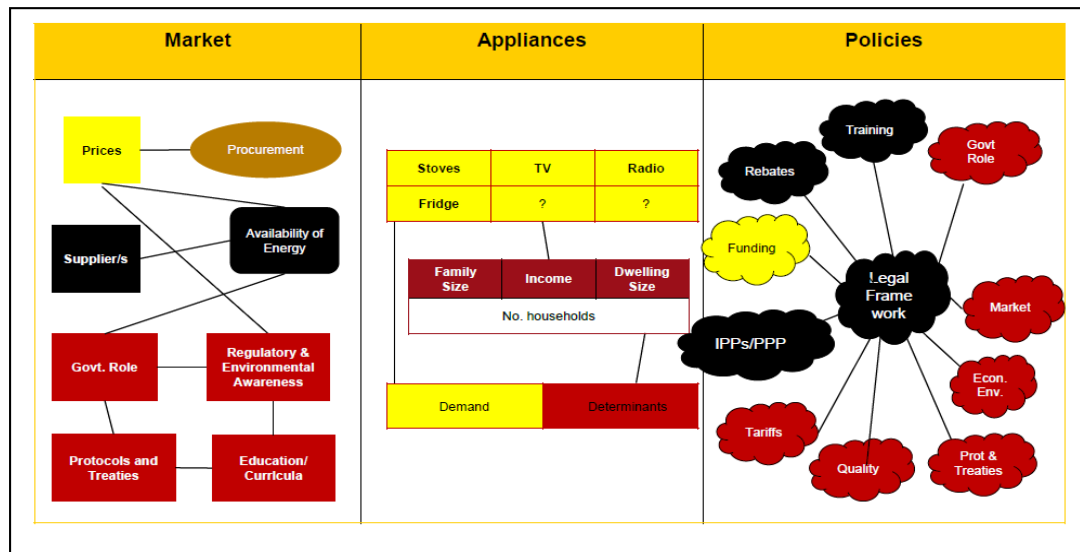


Figure: 3 Roles in Mini Grids

The private sector should also play relevant roles in all mini-grid activities and it is remarkable how private enterprises surface when the right economic, legal, regulatory, and social conditions are available (Fig. 3). Private sector ranging from banking, financing, and micro---lending companies, specialized PV grids developers, solitary village level entrepreneurs, tailor their solutions and

capacities to innovate business models that allow them to thrive in the energy sector particularly the PV mini grid renewable systems within a well-structured regulatory environment [7].

3.2 Licensing and Regulations

Licensing requirements for project can take many forms, depending on their duration, specificity, approval process, and other conditions [8]. One of the key aspects of licensing lies in the accountability level that the licensee is subjected to with regard to the legal electricity framework (Fig. 3). Alternatively, licensing requirements are over prescribed and they deter or inhibit mini-grid deployment. A balance is needed between ensuring reasonable service at reasonable cost to consumers, and facilitating investments and reducing transactional costs and barriers.

Regulations, therefore, should foster fair tariffs, enforcement of standards to maintain quality of service, and provide a forum to address grievances, for both consumers and developers. Regulatory approvals should include environmental impact assessments to ensure environmental sustainability. Regulations should also allow RE mini-grids to qualify for meeting renewable energy targets for traditional utilities and facilitate their participation in the renewable energy certificate market for additional revenues. Regulated tariffs lead to affordability, for mini-grid consumers, as well as parity with central grid tariffs. Due to the wide range, in costs of mini-grid systems, regulating consumer tariffs has usually been accompanied by some form of subsidies (either from the government or the local electricity utility) to ensure financial viability. Therefore incentives or subsidies that complement regulated tariffs should be adequate, disbursed in a timely manner, and have minimal bureaucratic hurdles from the perspective of project developers and financiers. Inappropriately designed regulations and inefficient subsidy dispersal mechanisms impeded the financial viability of stakeholders and subsequently drive them out of the market. Industrial and professional associations can help in this regard by pro-actively providing timely and appropriate advice to government.

3.3 Training and Capacity Development

Specialised human capacities to built, manage, finance or regulate decentralized projects are generally absent in a system that has predominantly relied on central grid extension and operation as the main approach for providing electricity access [9]. For successful development of the mini-grid systems, human resource, training and capacity development are essential for all stakeholders on the value chain. Universities and colleges need to adapt their curricula to include RE modules. On the other hand, project developers, government ministries, regulators, local distribution utilities, financial service providers and the communities need to develop synergies to reflex PV renewable systems as reliable sources of energy. Government policies and programs should facilitate and finance training and capacity development of different actors, in RE and mini grids in particular, across the entire education system. PV renewable systems activities should also be taken on board by international organizations as demonstrated by, the African Development Bank, World Bank, African Union, European Union,

UNIDO, among others [9]. Providing training to local financial institutions in order to increase their understanding of PV mini grids and related benefits is also very cardinal.

3.4 Monitoring and Verification

Since off-grid system deployment is essentially a decentralized business, monitoring and verification (M&V) at four different levels is critical to make sure that technical standards are met and that specific processes are carried out as they should. At the same time, the remoteness and isolation of many PV systems makes M&V expensive and difficult. So the use of local highly trained and skilled human resources is of uttermost relevance. Experience show that monitoring and verification should be enforced due to the following:

- i. M&V is essential for verifying that appropriate construction codes and standards are being followed. Technical monitoring includes performance of the generation unit, switchgear, maintenance, electricity production and energy or fuel consumption in case of a hybrid system. M&V of key parameters through an efficient on line monitoring system is critical for projects that rely on performance-based subsidies as well as those that receive credits through a renewable energy certificate mechanism or a carbon abatement program like the Clean Development Mechanism.
- ii. Commercial and financial monitoring is related to adequate tariff charges, they are regulated to ensure proper capital subsidy disbursal, so that the sanctioned projects are built as per specifications. Also commercial and financial monitoring sustains grid operations by adequately carried out, maintenance, meter reading, billing, revenue collection, and penalties.
- iii. Consumer grievance redressal is a specific monitoring and verification mechanism that allows the customer an expedited mechanism to file complaints and receive adequate post-sale services. However, consumers need to be monitored so that they honour their contracts regarding consumption levels, payments and penalties.
- iv. Appliance standards are relevant since highly efficient appliances can significantly reduce grid overload and help achieve demand-side management objectives.

3.5 Financial Incentives, Financing and Tariffs

PV stakeholders may be able to draw upon three broad categories of funding to support a mini-grid project over its entire lifespan. That is, financial incentives and subsidies from government; financing in terms of debt and equity from banks and investors; and consumer tariffs from rate payers in the community. The balance among these resources dictates the scalability, equitability and long-term sustainability of mini-grid development. Figure 4 shows the three financial flows that the project developer (private, community or government) has to rely on to successfully ensure the long-term financial viability of the project.

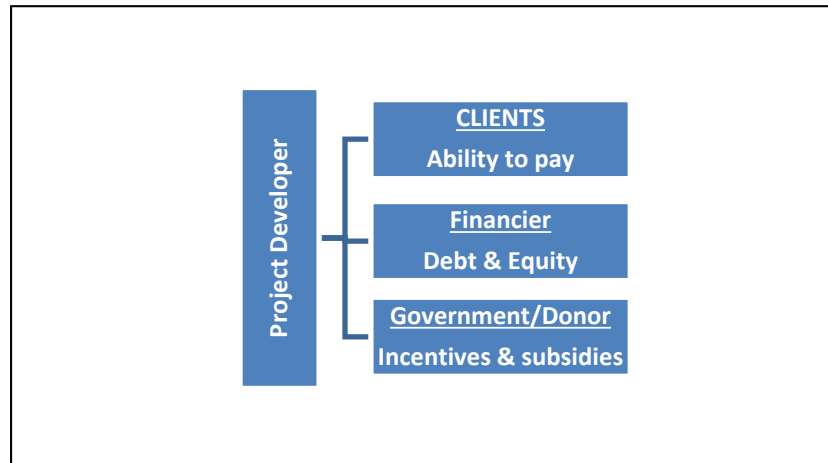


Figure 4: Financial flows for a mini-grid system

Financial incentives and subsidies, both upfront and ongoing, reduce the requirement for financing, and can result in affordable tariffs for consumers. Appropriate financing mechanism can reduce the subsidy burden on government and utilities, while allowing developers and operators to recoup their investment. Appropriate tariffs and tariff structures can also ensure equitability and affordability for consumers while providing adequate returns to investors [10]. Where subsidies are provided, schemes need to include provisions for dealing with their phase out.

3.6 Financial Incentives and Subsidies

Financial assistance provided by governments, utilities, and international aid agencies and donors can prove critical in developing countries, especially when committed on long term beyond the pilot project stage. Financial assistance covers different funding streams that cater to stakeholders, usually project developers and consumers, in order to allow a combination of scalability, equity, and economic sustainability.

There are several different forms of subsidies and support that various governments have adopted. Capital subsidies are the most common form of support that reduces the upfront capital costs of a RE mini-grid [9]. These capital subsidies may be linked to ongoing performance, in the economy or energy sector, and disbursed in specific time intervals to ensure service delivery by project developers.

3.7 Financing and Investment

Financing and investment is critical for the development and scalability of RE mini-grids. Financing is usually offered by government or domestic or international banks, while private investors can provide equity [5]. The uncertainty of mini-grid operation over the long term is coupled to availability of investment, because the associated risk can result in high interest loans. Government fiscal policy, to commercial banks, that provides a long-term signal to the sector can reduce the investors' risk perceptions. Government-owned banks can also provide low interest loans to the sector. Interest subsidy from the government can also reduce the rates for loans [11]. Finally, collateral subsidy, usually in the form of a fund, can guarantee a financing institution payment in case of default from the borrowing entrepreneur, thus shifting the risk from the financier to the government institution [12].

3.8 Tariffs and Revenue Streams

There are several tariff designs that have been used in mini-grid operations [6]. The simplest one is the fixed charge based either on connection or on number of lights and appliances. Fixed connection charges are often accompanied by load limiters to limit the number of appliances, i.e., load per connection. However, simple load limiters restrict consumer demand at all times, even during non-peak hours. Smart load limiters can be capable of restricting consumer demand only during peak load times by sensing the voltage or frequency to determine the stress on the mini-grid system [6]. In the absence of a load management strategy, mini-grid systems with fixed connection charges can eventually fail as consumers add appliances and demand exceeds supply.

Energy-based tariffs, on the other hand, require consumers to pay for the actual energy they use by metering their consumption. Such tariff schemes may also encourage conservation. Time-of-use meters, although more expensive, could further incentivize conservation during peak hours. However, energy meters and the associated costs of metering, billing, and maintenance can form a significant portion of the overall cost of providing electricity access, especially to rural consumers who are often dispersed and have low consumption levels. Pre-paid meters that require consumers to purchase units of electricity from the supplier in advance can avoid the task of meter reading, billing, and collection [6]. However, such tariff schemes may also need load limitations to prevent peak demand exceeding supply.

Further the tariff scheme, whether power or energy-based, depends on the type of technology used. Solar photovoltaic systems and other systems using battery storage are limited in energy supply, while micro-hydro or biomass gasifier-based systems are limited in the level of peak load that they can meet. In places where mini-grid tariffs are unregulated, the project developer and the consumer community are free to decide the structure of the tariff design, including penalties for non-payment. However, the results can be quite varied, from tariffs being insufficient to cover generation costs to developers charging relatively high tariffs.

4. Socio-Economic Benefits

Socio-economic benefits are key drivers for renewable energy deployment particularly for mini grids. With many economies characterised with low growth, policy makers see potential in mini grids for increased income, improved trade balance, contribution to industrial development and job creation. However, analytical work and empirical evidence on these topics remain relatively limited. Environmental benefits can also be created from mini grids renewable systems.

The major benefits, from mini grids renewable systems, can be classified as: macroeconomic, distributional, energy system-related and other cross-sectoral (additional) benefits. To this effect this paper focuses on one category of effects, namely macroeconomic, within which four variables are addressed – value addition, gross domestic product, welfare and employment. At macroeconomic level PV min-grids can directly lead to [13].

- i. Improved economy by creating new jobs;
- ii. Reduced dependence on imported fossil oils with makes up a huge proportion of national energy budgets in most developing countries;
- iii. Reduction in air pollution and improved livelihood,
- iv. Improved quality of life; and
- v. Improved education through after school studies.

Overall socio-economic benefits can be measured along the different segments of the value chain, such as project planning, manufacturing, installation, grid connection, operation and maintenance and decommissioning. Further opportunities for social economic benefits exist in the supporting processes such as policy-making, financial services, health, education, research and development and consulting.

The Human Development Index (HDI) quantifies human development by considering school enrolment and literacy rates as a measure of education level; life expectancy as a measure of health care level; and per capita GDP based on purchasing power parity as a measure of material wealth level. The HDI is an average of three component indices: the education level index (EL_I), life expectancy index (LE_I) and per capita gross domestic product index based on purchasing power parity i.e. income level index (IL_I).

$$HDI = \frac{EL_I + LE_I + IL_I}{3} \quad Eq. 1$$

Each of the variables, in Eq. 1, depends on energy flow resources in the national systems. In the planning segment, social economic benefits are mostly created by the engagement of specialised individuals and companies to conduct resource assessments, feasibility studies, project designs, legal activities, etc. The economic spin-offs, in this regard, are huge. There is potential for many companies or consultancies to get involved especially for solar power plants, which includes many steps, such as basic scoping, concept engineering and geographical determination.

Similarly, social economic benefits can be created in each step of manufacturing, from the sourcing of raw materials, to component manufacturing and assembly. That is, mostly from labour-intensive activities involving civil engineering infrastructural works and assembling of wind or solar plants. For photovoltaic plants, social economic benefits are created at different levels from the production of silicon to manufacturing modules, and additional components such as inverters, mounting systems, charge controller boxes, etc. Manufacturing solar power plant components, such as mirrors, receivers and power blocks, involve different industries, with numerous potentials for local social economic benefits. In developing countries, concentrated solar power technology components such as bent glass for the parabolic mirror need to be produced by highly specialised manufacturers. Hence, the potential for social economic benefits creation in Africa is not applicable to all markets and differs according to the solar power technology chosen. For instance, a large portion of the components of a central tower can be manufactured locally compared to a parabolic trough which is highly specialised. The presence of other industries with similar processes can facilitate the development of a local solar industry and social economic spin-offs.

5. Conclusion

The importance of integrating mini grid systems, in terms of RE sustainability, financial environments, community participation, and related social economic benefits in electricity access efforts cannot be over emphasised. Concerted efforts, by policymakers, industry and communities, in context of national policies, institutional and financial frameworks ensure the success of the mini grid programs. Therefore:

- i. Renewable energy- mini---grids are important alternatives complementary to central grid extension as a way of increasing access to reliable electricity and services. Most successful mini-grids have been developed where designers have carefully considered sustainable financial models, local economics, social and environmental conditions; coupled with well-articulated national policy and regulatory framework.
- ii. PV Mini Grid Schemes need to be supported by a range of local services, sustained local expertise and skills to facilitate maintenance. Key educational institutions are needed to develop training, research and innovation skills programmes. Supporting measures can include; funding; building competence; and developing infrastructure in universities and colleges.
- iii. Increasing local understanding of the technical aspects of PV grid schemes, rules and regulations surrounding aspects such as fee payments, can help reduce conflict and problems. The presence of companies at the local level that can provide energy products, services, and replacement parts is also important in integrating mini-grids into a more sustainable local energy infrastructure.

- iv. Supporting mini grid awareness programs within government, private sector, industrial associations, non-governmental organisations and legislative institutions.
- v. In community schemes there is need to extensively consult communities to build trust, establish sufficiently clear management structures and incorporating locals in the structures. Failure to include local leaders, especially in rural areas, has been perceived as a threat to their positions, resulting in improper maintenance and even the disconnection of the system. Other than there is schemes need to include provisions for dealing with unforeseen risks, such as dispute resolution procedures and some form of independent monitoring (e.g. of payment systems).
- vi. Sustainable financing is one of the main priorities for success. Schemes where sufficient funds have been secured upfront are likely to succeed. Before carrying out detailed design and the construction of high quality infrastructure, financing models that at least cover operation and management costs over the project lifetime (usually 20-30 years) ought to be developed. This is a complex process and success depends upon the operator's decisions and the external environment.
- vii. Supporting local financial institutions reduce perceived risks, such as credit enhancement through partial risk guarantees provided by donors or supporting partnerships between financial institutions and energy is also important. Where subsidies are provided, provisions dealing with project phase out need to be included. On the other hand local financial institutions should increase their understanding, in mini grid projects, through tailor made trainings. Cooperation and mutually beneficial cohesive actions by financial, private and public sectors, industrial associations and international organisations can help ensure the success of existing policies. To this effect reducing transaction costs, through standardization of administrative procedures and time for approval of schemes, establishing transparent tariffs and the legal procedures are important.
- viii. Policies that stimulate deployment, aim at building a domestic industry by encouraging investment and technology transfer, strengthening capabilities, promoting education and training, as well as research and innovation greatly affect social economic benefits creation. It is, therefore, important that policy makers develop an appropriate mix of policies tailored to country conditions and priorities.
- ix. Government or donor led initiatives need to incentivize private sector participation while limiting market distortions. These initiatives may include among others output-based aid subsidies; advanced market commitments; long term contractual concessions and licenses to stimulate private investments and cost recovery. The Subsidies need to be designed to support market development, rather than hardware, and to subsidise access (e.g. upfront connection fees for consumers) rather than operating costs.
- x. The socio-economic benefits, of solar renewable energy technologies, are increasingly driving their adoption and deployment due to the potential of improving job creation and income; trade balance; quality of life; and industrial development. Socio-economic benefits and related opportunities, on the value chain, exist during project planning, manufacturing, installation, grid connection, O&M and decommissioning. Although these benefits vary on the value chain, benefits accrue to specialised individuals and companies that conduct resource assessments and feasibility studies, legal activities, source raw materials, manufacture and assemble sub-components.

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