Modelling the Sustainability of Solar PV Mini Grid Solutions for the Rural Off Grid areas in Nigeria

Hafiz Bello

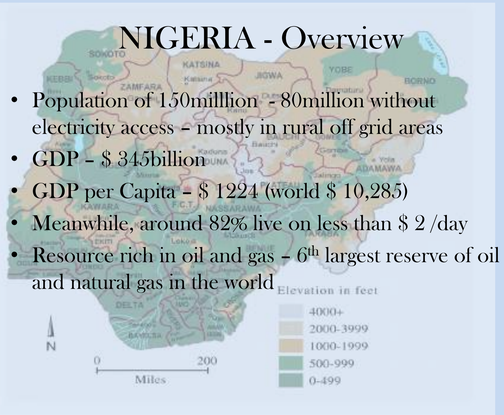
Supervisor: Dr. Rocio Diaz Chavez

ABSTRACT:

Modern energy provision and electricity in particular is widely regarded as the missing millennium development goal. Decentralized generation and distribution using renewables is often advocated as a least cost option for the rural communities, but there has been limited insights into how the contribution to socio economic development will be practically and pragmatically achieved. In the short term, it is difficult to analyse what bearing the electricity delivery has on the envisaged long-term future in rural Nigeria. For an end use oriented planning of the electrification system such as suggested in this research, there needs to be an attempt to understand how developments in markets, attitudes, policies and behaviours co-evolve with the introduced innovation in the envisioned acceptable future system. These dynamics needed for "eco-restructuring" are complex, poorly understood and paid insufficient attention during policy making and rural electrification project execution. This is a key cause of a failure of projects to achieve scale and falling short of expectations in the energy and economic development sectors.

INTRODUCTION:

NIGERIA - Overview



- Population of 150milllion - 80million without electricity access – mostly in rural off grid areas
- GDP – $ 345billion
- GDP per Capita – $ 1224 (world $ 10,285)
- Meanwhile, around 82% live on less than $ 2 /day
- Resource rich in oil and gas – 6th largest reserve of oil and natural gas in the world

Research Question

- What are the systemic alignments or conflicts on the provision of renewable technology with the current rural energy landscape?

Objectives

i. To investigate the interfaces between rural energy provision and common pool resource factors with respect to decentralised electrification solutions.

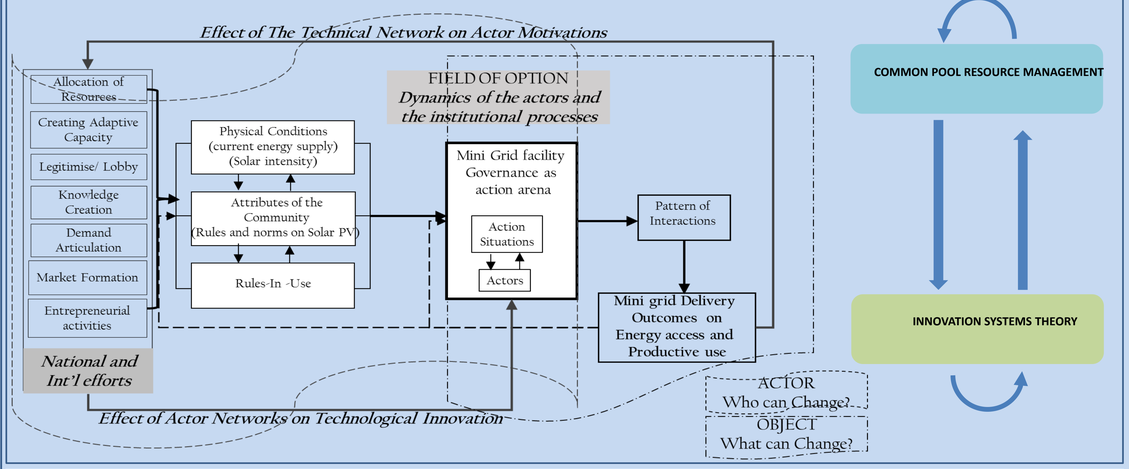
ii. To determine the effect of the technical network on the motivation of actors within the rural energy landscape to sustain the growth or continued use of technology.

PROBLEM STATEMENT – THE POLICY VOID – THE GIFT AND THE CURSE

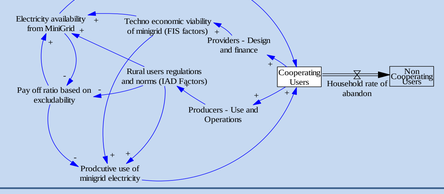
In Nigeria, the activities around energy provision less than 100kW is largely unregulated. Therefore, the kW space faces a lack of consistency on the assumed causal linkage between provision of energy services and economic development. This gap can be conceptualised as a dynamic behaviour over time that creates conflicting outcomes for both the provider and users which might not match what was intended.

This study presents an understanding of the dynamic and complicated processes of the actors and decision-making processes within off grid rural contexts for solar PV mini grids by looking at the co-evolution of the technological innovation system (FIS) and the common pool resource (IAD) issues within the geographical context has been shaped about the existing governance actors and produced certain outcomes

CONCEPTUAL FRAMEWORK – Illustrating Innovation systems and common pool resource interactions



Core Mechanism of the model



The core mechanism of the merged model and contains the multiple interacting feedback loops that constitute the hypothesis of how the relationships between the system components and variables are an indication of a positive reinforcement towards sustainability and vice versa. It is thus considered the fundamental structure of the system dynamics model driving the outcomes of the use of mini-grid solar PV infrastructures in off grid rural areas of Nigeria and is denoted the FIS-IAD constellation.

REFERENCES

Ikeme J., Ebohon O. J., (2005) - Nigeria's electricMezher, T., Dawelbait, G., & Abbas, Z. (2012).OPEC, (2012) – Organization of PetroleumRenewable Energy Ventures (2013) – Powering power sector reform: what should form the keyRenewable energy policy options for Abu Dhabi:Exporting Countrries (OPEC), Annual statisticalAfrica through Feed –in tariffs – Advancing objectives? - Energy Policy 33 (2005) 1213–1221 Drivers and barriers. Energy Policy, 42(0), 315-bulletin, 2012 -renewable energy to meet the continent's electricity Karekezi S., Kimani J., (2002) - Status of power328. doi:http://www.opec.org/opec_web/static_files_project/ needs - World Future Council – Heinrich Boll sector reform in Africa: impact on the poor -http://dx.doi.org/10.1016/j.enpol.2011.11.089 media/downloads/publications/ASB2012.pdf Stiftung. Energy Policy 30 (2002) 923–945. Mitlin D. (2008) - With and beyond the state –co-Oseni M. O, (2011) – An analysis of the powerSambo A.S., Iloeje O.C., Ojosu J. O., Olayande J. Kemp R., van Lente H., (2013) – The dualproduction as a route to political influence, powersector performance in Nigeria - Renewable andS., Yusuf A.O., (2006) – Nigeria's experience challenege of sustainability transitions: differentand transformation for grassroots organizations -Sustainable Energy Reviews 15 (2011) 4765– 4774.Sawin, J. L. (2004). Mainstreaming renewable trajectories and criteria pg 115 – 132 inEnvironment & Urbanization, (IIED) Vol 20(2):Ostrom E. (1996) – Crossing the great divide –energy in the 21st century (Vol. 169): Worldwatch Innovations in Sustainble Consumption – New339–360. Coproduction, Synergy and Development - WorldInstitute Economics, socio technical transitions and socialNBS, (2013) – National Buraeu of Statistics –Development, Vol. 24, No. 6, pp. 1073-1087 Sonibare J.A. (2010) - Air pollution implications of practices edited by Cohen M.J., Szenwald BrwonGross Domestic Product of Nigeria – 2012 andPercy S.L. (1984) – Citizen Participation in the Co-Nigeria's present strategy on improved electricity H., and Vergragt P.J – published by Edward Elgarestimate for Q1, 2013 – www.nigerianstat.gov.ng Production of Urban Services – Urban Affairsgeneration – Energy Policy 38 (2010) 5783–5789. publishing limited, Cheltenham, United Kingdom. Ohuankin S.O., Ojolo, S.J., Ajayi O.O., (2011) -Review 1984 19: 431. Toth F.L, Rogner H-H (2005) - Oil and nuclear Lipp, J. (2007). Lessons for effective renewableSmall hydropower (SHP) development in Nigeria:REAP, (2006) – Renewable Electricity Action Planpower: Past, present, and Future - Planning and electricity policy from Denmark, Germany and theAn assessment - Renewable and Sustainable- a framework for the implementation of theEconomic Studies Section, Department of Nuclear United Kingdom. Energy Policy, 35(11), 5481-Energy Reviews 15 (2011) 2006–2013. renewable electricity policy and regulatoryEnergy - International Atomic Energy Agency 5495. Okojie C., (2009) - Decentralization and Publicguidelines by the International Center for Energy,(IAEA) - Energy Economics 28 (2006) 1 – 25 - Mabogunje A.L (1967) – Systems approach to aService Delivery in Nigeria, Nigeria StrategyEnvironment and Development (ICEED) with thedoi:10.1016/j.eneco.2005.03.004. theory of Rural-Urban Migration. Support Program (NSSP) Background Paper No.Federal Ministry of Power and Steel, Nigeria. UN, (2012) – United Nations Population Division Mallon, K. (2006). Renewable Energy Policy And004. Reiche, D., & Bechberger, M. (2004). Policyof the Department of Economic and Social - Politics: A Handbook For Decision-making:Omenikolo,I.A., Amadi, R.O. (2010) - Challengesdifferences in the promotion of renewable energiesWorld Population Prospects: The 2012 Revision, Earthscan. facing Nigerian local content in oil and gas industryin the EU member states. Energy Policy, 32(7),http://esa.un.org/unpd/wpp/index.htm Manzini F., Islas J., Macias P., (2011) – Model for- Continental J. Renewable Energy 1: 15 - 20, 2010.843-849. doi: http://dx.doi.org/10.1016/S0301-jects – evaluating the environmental sustainability ofOnwuka K. O., (2013) - Nigeria Vision 20: 2020: A4215(02)00343-9 energy proTechnological forecasting and social change 78 (2011) 931-944.

CASE STUDY OVERVIEW, METHODS AND FINDINGS:

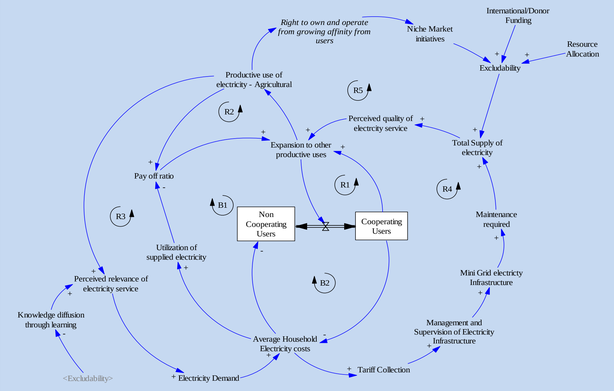
ONIBAMBU MINI GRID PROJECT, OSUN STATE, NIGERIA

17/08/2017 -17/09/2017

24kW MINI GRID INFRASTRUCUTURE, 112 QUESTIONNAIRE SURVEYS
14 EXPERT SEMI STRUCTURED INTERVIEWS

METHODOLOGY:
ANALYSIS OF MODEL BEHAVIOUR - FEEDBACK LOOP ANALYSIS:

Using the cooperating user stock as the node, a loop analysis using Vensim identifies 7 major loops whose complex interactions dictate the sustainable or otherwise outcomes for the mini grid delivery model. Table 1 includes a description of the important feedback loops in the causal loop diagram. These loops represent a summary of the FIS-IAD interactions and represent the field of options

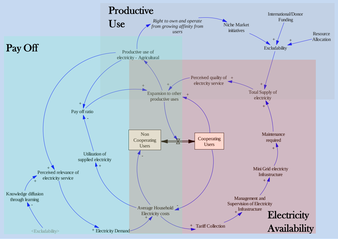


Causal Loop diagram of the FIS-IAD institutional configuration determinants for sustainability, showing the reinforcing and balancing loops

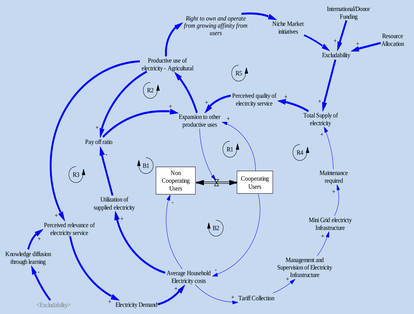
Table 1: Important feedback loops representing the field of options

Loop	Name	Description
R1	Capacity to cooperate	The expansion to productive use of the mini grid increases the stock of cooperation of the users while also increasing the capacity of existing non-cooperative users to become cooperative users.
R2	Agricultural Productive Expansion benefit	Using electricity for agricultural productivity increases the payoff (cost/benefit) perception of users thereby increasing their willingness to pay higher tariffs if need be.
R3	Mutual Understanding difference gap	Choice rules by the providers of the mini grid have presented electricity availability at household level as the consumption norm therefore, the capacity costs needed for expansion for productive usage is seen as an inconvenience resulting in less productive usage.
R4	Scalable assurance	The current arrangement on pre-paid household electricity costs is easing tariff collection by the community level management organisations put in place by the providers. This is positively reinforcing the idea that the mini grid delivery model is a possible solution that can spur socio economic growth.
B1	Recreational Utilization level	Stable household electricity costs limits the utilization level to that of recreational use which in turn lowers the payoff ratio to users and the expansion to productive use. This loop counterbalances the mutual understanding difference gap loop R3.
B2	Household cost stability	There is also an influence played by the understanding of the users on the suitability of the mini grid to meet their needs and the mode of tariff collection in terms of timing and frequency. This loop counterbalances the scalable assurance loop R4
R5	Transaction costs challenge	Exclusion technologies do influence niche market initiatives negatively. This reduces continued cooperation from users who have developed an affinity to own and operate the mini grid to meet their needs.

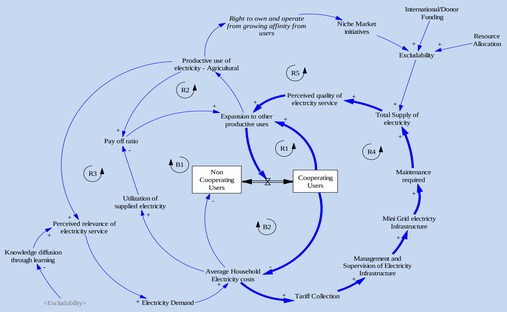
FINDINGS



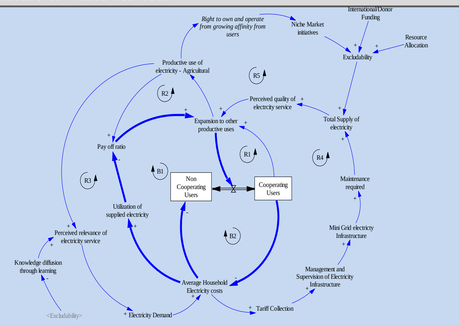
Finding 1 - Causal Loop analysis of the FIS-IAD institutional configuration determinants for sustainability, showing sub systems. The sub systems are crucial to understanding the effect of the reinforcing and balancing loops



Finding II - Feedback loops related to the balance of control between the providers and the producers of the infrastructure are predominantly reinforcing excludability thereby affecting utilization levels to prevent the expansion of the infrastructure to other services



Finding III - feedback system for the authorised actions for the set of participants. Representing the perception on the effect of the entry conditions and the positions allowed by the community managers of the mini grid as building blocks toward cooperative usage



Finding IV - feedback system for the balancing loops showing that expansion to productive usage is due mainly to the design and finance choices of the providers and less on the current energy practices by users stunting the growth of information rules and learning by doing

CONCLUSIONS

In summary, the balancing loops are dominant because the providers hold the gatekeeping powers of the management of the infrastructure, they have a monopoly on any modifications in the use and operation of the mini grid infrastructure which is way beyond their design and finance responsibilities thereby driving unsustainable outcomes. This shows that over time, the capacity to cooperate by the users will wane due to asymmetry on the information around the economic capabilities.

If the sustainability of this institutional delivery method is to be achieved, there needs to be a recognition of to answer the following;

i. 'what can change' in terms of adverse selection by lowering transaction and capacity costs driving the imbalance on the benefits accruing to just the providers of the mini grid infrastructure

ii. 'who can change' in terms of moral hazard outcomes by growing the affinity of users through bridging the gap between the mutual and cognitive norms of the providers and users driving the information asymmetry which is preventing the niche markets from emerging. Therefore, what this perspective suggests is that the stock of users will continue to grow and ensure a governance towards sustainable outcomes that if both the adverse selection and moral hazard outcomes