THE OPPORTUNITY FOR JOINT DEPLOYMENT OF POWER AND TELECOMMUNICATIONS INFRASTRUCTURE IN UGANDA

By

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Abstract

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The Opportunity for Joint Deployment of Power and Telecommunications Infrastructure in Uganda

Thesis directed by Martin Taschdjian

Joint deployment of power and telecommunication infrastructure will lead to better development outcomes through improved utility of telecommunication services in Uganda. This research examines the independent deployment of power and telecommunications infrastructure in Uganda, and determines how and where opportunity for joint deployment arises.

It is found that joint deployment may be based on the electric grid or wireless base station infrastructure and that the opportunity for joint deployment is greatest in rural and remote areas for the development of new infrastructure. The accrual of scope economies for joint deployment based on the electric grid results in greater economic incentive for joint deployment in areas with dense population and smaller gaps in infrastructure. Economic incentive for joint deployment in areas with larger gaps in infrastructure is spread amongst various stakeholders involved in the development of power and telecommunications infrastructure in rural areas.

While changes in policy will be required to align incentives amongst stakeholders for areas with larger gaps in infrastructure, weaknesses that exist in the policy frameworks will have to be overcome in order to fully realise the opportunity for joint deployment.

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ACRONYMS

BECS	Bundibudgyo Electric Cooperative Society
ERA	Electricity Regulatory Authority
MEMD	Ministry of Energy and Mineral Development
MoICT	Ministry of Information and Communications Technology
MofPED	Ministry of Finance, Economic Planning and Development
FESL	Ferdsult Engineering Services Limited
NDP	National Development Plan
NITA	National Information and Technology Authority
PACMECS	Pader Abim Community Multi-purpose Electric Cooperative Society
REA	Rural Electrification Authority
REB	Rural Electrification Board
REF	Rural Electrification Fund
RCDF	Rural Communications Development Fund
UCC	Uganda Communications Commission
UEDCL	Uganda Electricity Distribution Company Limited
UEGCL	Uganda Electricity Generation Company Limited
UETCL	Uganda Electricity Transmission Limited

Chapter 1 Introduction

As of January 2009[1], only 10% of Uganda's population had access to electricity. Given that 85% of the population in Uganda resides in rural areas, the fact that the electric grid is concentrated in urban areas means that most people in Uganda do not have access to electricity.

Yet, in spite of this, almost 80% of the population[2] live within coverage area of mobile telephony service, with teledensity at 47% and an estimated 5.7million Internet users[3]. Significant challenges however persist in the operation and expansion of existing wireless network infrastructure, due to the unreliable and limited availability of electricity. With the cost of powering base stations forming a significant portion of operational expenditures for telecom network operators[4], services remain unaffordable for many, especially the rural population and further expansion and upgrade of services is threatened.

Nevertheless, the government is taking advantage of the increased availability and access to ICT to improve the delivery of social services such as health, and education, in an effort to achieve the development goals for the country. However, full utility of telecommunication services for development will not be achieved without better access to power, and based on this assertion, it is hypothesized that power and telecommunication infrastructure in Uganda should be jointly rolled out.

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[1] More recent estimates put the grid electrification rate in Uganda at 13% with 5% being the rate so far achieved for rural areas. "Geothermal Power Plant to Add 150 Megawatts," accessed April 20, 2013, http://www.newvision.co.ug/news/641836-geothermal-power-plant-to-add-150-megawatts.html.

[2] "Powering Telecoms: East Africa Market Analysis," 9, accessed March 22, 2013, http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/10/GPM-Market-Analysis-East-Africa-v3.pdf.

[3] "UCC Annual Market Review 2011-12.pdf," n.d.

[4] "Powering Telecoms: East Africa Market Analysis," 11.

The purpose of this research therefore, is to examine the opportunity for jointly rolling out power and telecom infrastructure in Uganda, so as to enable access to both power and telecommunication services, by answering the question - What are the options for joint deployment in Uganda?

The study will examine how and where options for joint deployment arise from a technological perspective and whether economic incentives for the exploitation of these options exist. The policy and regulatory environment in Uganda will also be assessed to determine what barriers exist and potential remidies to overcome these barriers in order to promote joint deployment.

Methodology

The research will be done through a review of relevant literature on independent and joint power and telecommunications infrastructure development, as well as inductive and deductive analysis of this information.

Overview of Sections

Chapter 1 provides background information about Uganda in order to provide context for the research. Chapter 2 and 3 then examine the independent deployments of power and telecommunications infrastructure to enable the identification of opportunities for joint deployment. The options for joint deployment are identified from a technological perspective within chapter 4 and a gap analysis is carried out to identify areas in Uganda where the identified forms of joint deployment could play a role in improving availability and access to power and telecommunication services.

Chapter 5 then presents an assessment of whether economies of scope exist, as well as an investigation of the economic incentives for the implementation of joint deployment followed by chapter 6 which reviews the policy frameworks in

Uganda to identify potential barriers to joint deployment and what changes could be made to promote the joint deployment of power and telecom infrastructure in Uganda. A summary, recommendations and conclusion are then made in chapter 7.

Background

General Information about Uganda

Location

Uganda is a landlocked country located in East Africa along the Equator and as such has a tropical climate with semi-arid areas in the north of the country.

Figure 1: Map of Uganda showing neighbouring countries and major towns

Source: CIA World Factbook

Demographics and the social economic situation

Uganda has an area of 241,550 square kilometres and a population density of 123persons/km^2. The country has one of the fastest population growth rates at 3.2% with the current population estimated to be 34million people.[5] Over 50% of this population is below the age of 18years.[6] Although the rate of urbanisation is

[5] Uganda Bureau of Statistics, *Microsoft Word - Statistical Abstract Cover - 2012StatisticalAbstract.pdf*, 9, accessed April 19, 2013, http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/2012StatisticalAbstract.pdf.

[6] Ibid.

growing, only 5 million people currently live in urban areas[7]. The government provides free education for the first 4 years of primary school and secondary school and the literacy rate[8] is 73%.[9] The national language is English.

The Gross Domestic Product (GDP) as of 2012 is $17billion and has been growing over the past 5 years at an average rate of 6%.[10] Agriculture being the main economic activity employs 67% of the working population with the median wage being about $40.[11] Uganda is endowed with various natural mineral resources and recently started the exploration of oil reserves with the first products expected to be available in 2017.[12]

Administrative and political organisation

The country is governed by an executive (central government) that is led by a democratically elected president with a cabinet of appointed ministers who oversee government programs run through the various ministries within the country. The country is administratively divided into districts with non-autonomous local governments that are financed by and report to the central government. As of July 2011, Uganda had 112 districts[13] with the capital city, Kampala, being located in Kampala district, which is the main administrative and commercial hub of the country. The legal system is a mixture of British common law and customary law. A legislative branch constituted by representatives from all districts is responsible for

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[7] Ibid., 10.
[8] Literacy is defined in Uganda as the ability to read and write meaningfully in any local language.
[9] Uganda Bureau of Statistics, *Microsoft Word - Statistical Abstract Cover - 2012StatisticalAbstract.pdf*, 16.
[10] Ibid., xiv,186.
[11] Ibid., 18.
[12] "When Will Uganda Start Producing Oil?," *The Observer*, accessed April 27, 2013, http://observer.ug/index.php?option=com_content&view=article&id=23418:when-will-uganda-start-producing-oil; "Total Sees Starting Ugandan Oil Production in 2017," *MarketWatch*, accessed April 27, 2013, http://www.marketwatch.com/story/total-sees-starting-ugandan-oil-production-in-2017-2012-09-28.
[13]There were 80 districts as of July 2007. Uganda Bureau of Statistics, *Microsoft Word - Statistical Abstract Cover - 2012StatisticalAbstract.pdf*.

making the laws that govern the country. A five year National development plan (NDP) guides the activities of the different sectors[14] that are implemented through annual programs run by the government ministries. [15]

Current situation of power and telecommunication in Uganda

Power Sector Overview

The electricity sector is one of the subsectors overseen by the Ministry of Energy and Mineral Development (MEMD) in Uganda. The Electricity Act of 1999 established the Electricity Regulatory Authority (ERA) to regulate the sector, and also unbundled the Uganda Electricity Board (UEB) creating the Uganda Electricity Generation Company Limited (UEGCL), Uganda Electricity Transmission Limited (UETCL) and the Uganda Electricity Distribution Limited (UEDCL). A Rural Electrification Fund (REF) was later established in 2001 under the oversight of the Rural Electrification Board (REB) following the recognition of the gross challenge for enabling access to modern energy services for the rural population.

Despite having more than doubled the electrification rate from 5% in 2002 to an estimated 12% in 2011, Uganda still has one of the lowest per capita electricity consumption rates at 75kWh/year compared to an average of 578kWh for Africa and 2,572kWh for the world. [16] Electricity supply deficits which result in rolling blackouts are regularly experienced due to the high rate of growth of demand for electricity driven by industrial users whose consumption constitutes the biggest proportion of demand.

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[14] The current National Development Plan spans the period 2010/2011 – 2014/2015 and encompasses four categories of sectors (i) Primary growth sectors where Information and Communication technology falls, (ii) Complementary Sectors where the energy sector falls (iii) Social sectors such as labour, education and health and (iv) enabling sectors such as the legislature

[15] "National Development Plan -Uganda.pdf," n.d.

[16] *Energy and Mineral Sector Performance Report 2008/09 -2010/11* (Ministry of Energy and Mineral Development, 2011), 15.

Most grid connected customers are located in the capital city and other major towns such as Jinja, Mbarara,Hoima and Gulu. [17] Given that the country is still in nascent stages of industrialisation and urbanisation, the demand for electricity is likely to continue growing strongly and as such, there is a challenge ahead to meet the existing need for electricity while also expanding electricity access to the rest of the population.

The NDP sets out an ambitious target for 15% electrification rate by the year 2015 and 100% electrification by 2035. [18] In light of this challenge, the government is aggressively pursuing the construction of new generation plants and encouraging the entry of Independent Power Producers (IPPs) to exploit the vast power generation potential that exists in the country. [19] An Indicative Rural Electrification Master Plan (IREMP) has also been developed to guide the extension of the distribution grid into rural areas as well as to direct off grid electrification efforts through the construction of mini grids and standalone power sources such as solar photovoltaic generation. [20]

Telecommunications sector overview

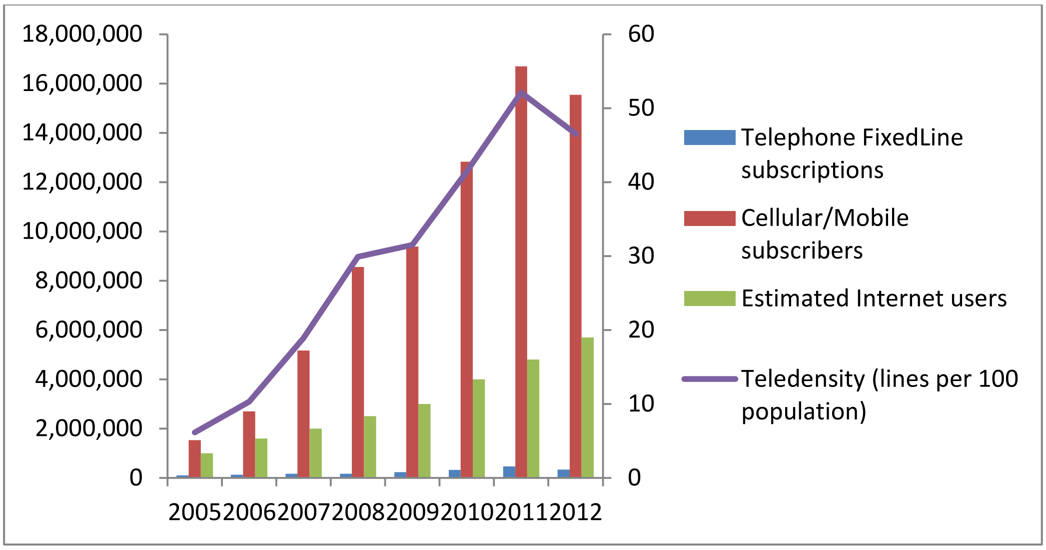
The telecommunications is sector is under the oversight of the Ministry of Information and Communication Technology (MoICT) which is tasked with developing policies to guide the growth of the sector. The Communications Act of 1998 established the Uganda Communications Commission (UCC) to regulate the sector and also mandated UCC to establish and administer a Universal Service

[17] "Uganda Energy Situation - Energypedia.info," accessed April 17, 2013, https://energypedia.info/wiki/Uganda_Energy_Situation#Energy_Situation.
[18] "National Development Plan -Uganda.pdf," 361.
[19] "2010 06 30 Developments & Investment Opportunities in Uganda's Electricity Generation Sectorxx.pdf," n.d.
[20] "Annual Report MINISTRY OF ENERGY AND MINERAL DEVELOPMENT 2011.pdf," n.d., 85.

Fund - the Rural communications Development fund (RCDF).[21] The RCDF facilitates the extension of telecommunication services to underserved areas in Uganda.[22]

The telecommunications sector in Uganda has experienced rapid growth since 2005 when the market was liberalised. Tele-density has grown from 6% in 2005 to 46% as of December 2012.

Figure 2: Trend of growth of fixed, mobile and Internet Users in Uganda



Source: Author - based on UCC statistics

This growth has occurred through the deployment of second generation (2G) Global System for Mobile Communications (GSM) networks in most parts of the country. 98% of telephone access is through mobile wireless service and fixed line telephone service is limited to Kampala and a few other major towns.

With the growing importance of Internet access, and more specifically broadband Internet service, the focus has now shifted to the deployment of

[21] The Uganda Communications Act of 2013 harmonised The Communications Act 1998 and The Electronic Media Act to form a new body,, still called UCC, but in charge of both telecommunications and broadcasting "UCC Act 2013.pdf," 5, accessed April 27, 2013, http://ucc.co.ug/files/downloads/UCC%20Act%202013.pdf..

[22] The RCDF Policy guides the interventions made in underserved areas. The targets set in the first policy, which expired in 2009, were all achieved and in some cases exceeded and a new policy was been developed to guide interventions for the period 2010 – 2014. "RCDF POLICY 2009 2010 – 2014 - RCDF_Policy_2011_2015.pdf," 1, accessed February 27, 2013, http://www.ucc.co.ug/files/downloads/RCDF_Policy_2011_2015.pdf.

broadband technologies. Telecom service providers have upgraded their networks to 3G technology in major towns where demand is concentrated in order to provide broadband services in these areas. Narrowband Internet access is what is mainly available in some rural areas.

The challenge ahead

The majority of the population in Uganda currently still have little or no access to power and broadband services. As the existing telecom infrastructure is upgraded to provide broadband services for the population, there is need to take into consideration the fact that the availability of reliable power is crucial for the provision and use of broadband services and that the lack of power will influence the affordability and gainful use of broadband by the population. It is therefore useful to assess how new infrastructure for power and telecommunications could be jointly rolled out or how existing infrastructure can be augmented to enable the availability of both power and broadband to a bigger part of the population.

Chapter 2 Power Network Infrastructure

This chapter provides an overview of the independent deployment of power network infrastructure in Uganda in order to provide a basis for identifying opportunities for joint deployment. First, an overview of the current international trend of development of power networks is given, followed by a discussion of the existing power network infrastructure in Uganda today including the plans for future development of this infrastructure. The chapter concludes with a discussion of the use of communication technology within power grid and off grid infrastructure, highlighting how this presents an opportunity for joint deployment.

Global trends in the development of power network infrastructure

Traditionally, power networks have been developed as centralised systems where the power generation source is located far away from the users. An electrical grid is then used to facilitate transfer of power to the users from the source through a high voltage transmission grid and lower voltage distribution grid.

Catastrophic failures of centralised grid power systems that have led to massive blackouts and economic loss, as well as the growing need for energy independence in light of diminishing fossil fuel reserves and global warming, have brought about change in the design and operation of power networks leading to the rise of what is commonly referred to as the "Smart grid".

The IEEE describes the term 'smart grid' as "a next-generation electrical power system that is typified by the increased use of communications and information technology in the generation, delivery and consumption of electrical energy".[23] The increased use of communications on the electric grid enables new capabilities for grid operators and end users.

[23] "About IEEE Smart Grid - IEEE Smart Grid," accessed May 6, 2013, http://smartgrid.ieee.org/ieee-smart-grid.

On the part of grid operators, due to the increased digitalisation of grid components, improved communications can facilitate better control and automation of functions such as fault location and protection. This in turn leads to higher efficiency and reliability of the system, since network faults can be located (or even prevented) and repaired faster thus preventing or reducing the length of power outages to consumers.

On the side of consumers, a smart grid will give them better control of when and how they use electricity as well as the opportunity to supply power to the grid. By allowing two way communications to and from the grid through Advanced Metering Infrastructure (AMI) systems, consumers will be able to receive real time pricing information which in turn will enable them to adjust their consumption accordingly. Additionally, users will be able to supply electricity to the grid through AMI and intelligent control systems on the grid, based on the concept of distributed generation.

Distributed generation is a key underlying concept of the smart grid as it will enable the widespread integration of electricity generated from renewable sources and lead to greater energy independence[24]. Distributed generation is said to occur where the "generating plant is serving the customer on site or providing support to a distribution network, connected to the grid at distribution-level voltages".[25]

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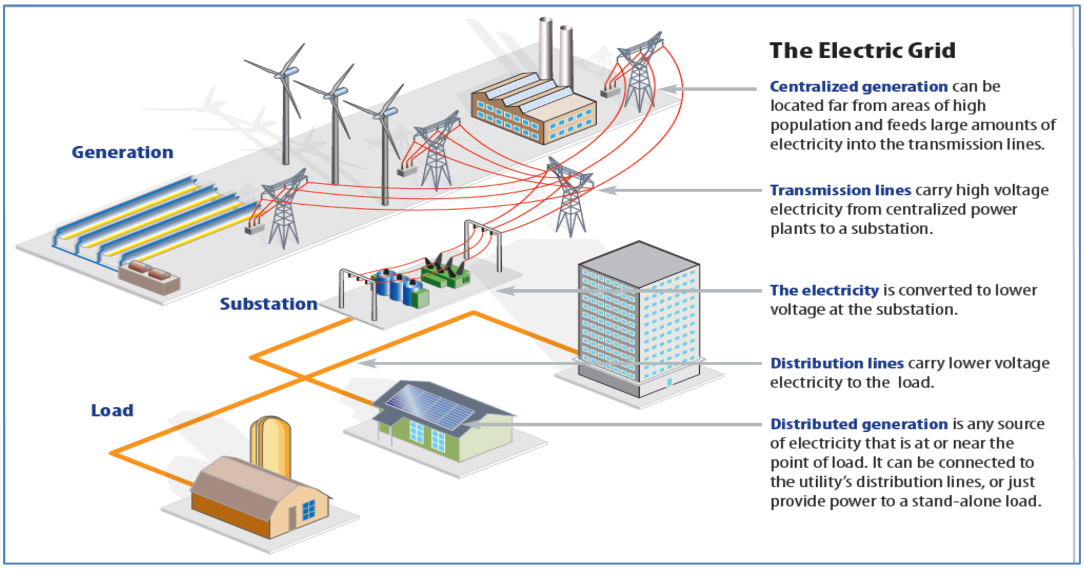
[24] Energy independence here refers to both the freedom of the electric from reliance on exhaustible fossil fuels as well as independence of electricity users from total dependence on utilities to meet their electricity needs.

[25] "Distributed Generation in Liberalised Electricity Markets," 19, accessed May 7, 2013, http://gasunie.eldoc.ub.rug.nl/FILES/root/2002/3125958/3125958.pdf.

Figure 3: The Electric Grid including a source of distributed generation



Source: NREL Publication

Within the smart grid architecture, various distributed generation sources may be combined in a micro grid that could operate as a part of or separate (islanded) from the grid.[26] This allows the advantages of integrating renewables to be leveraged while minimising the disadvantages or challenges of their integration.[27]As part of the grid, the micro grid could consume or supply power and provide other ancillary services to the grid while the islanded mode enhances reliability for users connected locally to the micro grid, in case of failures on the larger grid.

[26] The primary purpose of distributed generation is to meet a certain level of local demand and not to feed the grid. The imposition of mandated levels of renewable energy and feed in tariffs with premium prices to incent the deployment of wind and solar creates a 'gold rush' for the latter. Industrial-scale wind and solar generation plants are like traditional generation sources in that they produce electricity to meet demand elsewhere, and in the case of wind and solar often at great distances. They are geographically distributed, and this is one element of differentiation from conventional electricity generation sources, but this is because the fuel, wind and sunlight, is dispersed widely. This is not Distributed Generation ."The Smart Grid and Distributed Generation: A Glimpse of a Distant Future — MasterResource," accessed May 7, 2013, http://www.masterresource.org/2011/04/the-smart-grid-and-dg/.

[27] Robert H. Lasseter, "Microgrids And Distributed Generation," *Intelligent Automation & Soft Computing* 16, no. 2 (2010): 1,7.

The development of power infrastructure in Uganda

Uganda is pursuing a multi-pronged approach to electrification through the development of both grid and off grid power infrastructure.

Grid Infrastructure

Power Generation Infrastructure

Uganda has a vast array of energy resources available within the country that can be used for power generation, and yet power generation has continued to be a bottleneck for a long time now.[28] The existing installed generation capacity is 556MW although it is estimated that at least 5GW of renewable energy resources is available,[29] but is still unexploited for power generation.

The various efforts being made by the government to increase generation[30] have consistently been delayed, and as of 2012, the country was still experiencing electricity supply deficits.[31] Despite engaging a strategy of building generation through independent power producers (IPPs), the average duration for the planning, procurement and construction of large power generation facilities in Uganda is at least 5 years as evidenced in the cases of Bujagali and Karuma hydroelectric dams.[32] More success has however been registered in the cases of constructing smaller hydro generation plants (20MW and below) as 6 such plants currently supply the main grid or other smaller mini grids.[33].

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[28] "ElectricitySupplySituationUganda_Rugumayo.pdf," n.d., 10.
[29] "RENEWABLE ENERGY POLICY - RENEWABLE ENERGY POLIC9-11-07.pdf," 14, accessed April 30, 2013, http://www.rea.or.ug/userfiles/RENEWABLE%20ENERGY%20POLIC9-11-07.pdf.
[30]"UETCL Available Generation Capacity and Power Demand (MW)," accessed April 24, 2013, http://www.uetcl.com/images/control.pdf.
[31] Ibid.
[32] Bujagali hydroelectric dam (250MW) was expected online by 2011, however, it only started operation in mid-2012. Likewise Karuma dam also initially planned to come online by 2012, is currently still delayed by procurement irregularities
[33] "Annual Report MINISTRY OF ENERGY AND MINERAL DEVELOPMENT 2011.pdf," 7.

The slow increase of electricity generation means that demand continues to grow[34] ahead of supply resulting in unreliable electricity supply even for the 12% of Ugandans who have access electricity through the main grid. The continued unreliable supply of electricity therefore affects social economic activities that utilise electricity as an input, the provision and use of ICT being the relevant example in this context.

Power Transmission Infrastructure

The power transmission infrastructure in Uganda is operated by UETCL. UETCL is a public limited liability company with an operational mandate to be the sole purchaser and supplier of bulk power, to import and export electrical energy, to operate and perform the functions of system operator for the electricity transmission infrastructure in Uganda.[35]

The electricity transmission network in Uganda currently has a total length of 1300km, constituted of high voltage lines at 220kV (150km), 132kV (1368km) and 66kV (35.2km).[36] Although the transmission grid infrastructure is concentrated in the central region of the country, specifically Kampala where two thirds of the power is consumed, parts of it extend to the north east (Lira), far east (Tororo) and south west (Mbarara) of the country.

In addition to UETCL's role as single buyer and seller of bulk power and system operator, UETCL has to plan for the future grid requirements to meet demand and accommodate new generation, which function it carries out through the development of a grid development plan. The grid development plan guides the expansion of the transmission grid based on demand and generation forecasts over

[34] Demand was forecast to grow to at least 600MW at peak "Final Master Plan Report Vol I.pdf," n.d., 4 – 23.
[35] "Welcome to UETCL Official Website," accessed May 1, 2013, http://www.uetcl.com/.
[36] "Transmission Business," accessed May 1, 2013, http://www.uetcl.com/index.php?option=com_content&view=article&id=151:Transmission%20Business&catid=32.

a 15 year period.[37] Given the fact that 80% of the overhead lines within the transmission grid are over 45years old, the current plan which spans the period 2007 – 2022 includes major upgrades of the existing network as well as extensive new evacuation projects in light of the anticipated growth of new generation.[38] The grid expansions will also focus on increasing the coverage of the electrical grid by equitably distributing substations around the country to aid rural electrification and reduce power losses that result from the use of long distribution lines.

Power Distribution Infrastructure

As at the end of December 2011, 5 companies, UMEME Limited, Ferdsult Engineering Services Limited (FESL), Kilembe Investments Limited (KIL), Bundibugyo Energy Cooperative Society (BECS), Pader Abim Community Multi-purpose Electric Cooperative Society (PACMECs) were licensed to distribute electricity in Uganda.[39] FESL, KIL, BECS and PACMECs hold concession agreements with REA to operate grid extensions (mini grids that are connected to the main grid) that have been built as part of the rural electrification effort. BECS and PACMECs operate under a new management model introduced by REA in 2009 where rural cooperative societies, formed in the areas being served, are given the opportunity to manage the electricity infrastructure.[40] Of these companies, UMEME limited has the largest footprint having entered into a concession agreement in 2005 with UEDCL to operate, maintain and expand distribution infrastructure that existed when the state owned Uganda Electricity Board was unbundled.[41]

[37] *Energy and Mineral Sector Performance Report 2008/09 -2010/11*, 53–55.
[38] "Uetclbusinessplan.pdf," n.d., 39.
[39] "Electricity Sector Performance Report 2011.pdf," n.d., 29.
[40] "Rural Electrification Agency : Project Management Model," accessed May 2, 2013, http://www.rea.or.ug/?page=projects_model.
[41] "Uganda Electricity Distribution Company," accessed May 2, 2013, http://www.uedcl.co.ug/.

UMEME distributes over 95% of the electrical energy sold by UETCL. Its network distributes electricity to all major towns in Uganda but is concentrated in the south eastern part (Kampala and surrounding areas) of the country.[42]FESL operates in the south west of the country in the towns of Rukungiri-Kanungu, Kibaale-Kyenjojo-Kagadi, while KIL and BECS operate in the areas of Kasese and Bundibugyo in the west and PACMECs operates in the north east in Pader. UMEME took over from UEDCL an estimated total of 11,000km (6,700km of distribution lines at 33kV and 11kV and 6,500km of low voltage lines) and has managed to grow its network to 25,000km (11,000km at 33kV/11kV and 14,900km at low voltage) in 2012.[43] In addition to extending and refurbishing distribution lines, new distribution substations have been added to the network along with better metering and monitoring technologies such as SCADA and prepaid metering systems for end users.

In light of the planned increase in available electricity generation within the country and expansion of transmission infrastructure, UMEME plans to expand the distribution network and double its customer base within the next 7 years. Appendix 1 shows the customer growth experienced by UMEME since 2005

Other distribution network improvement efforts will include installation of new substations, replacement of conductors, automation of metering systems as well as enhancement of prepayment and other billing systems.[44]

Off-grid Power development in Uganda

In 2001, alongside other changes that took place within the energy sector, a Rural Electrification Strategy Plan was developed to guide interventions to address the very low levels of access to electricity in rural areas of Uganda. The two modes

[42] *Energy and Mineral Sector Performance Report 2008/09 -2010/11*, 43.
[43] "Umeme Annual Report 2012.pdf," n.d., 11.
[44] Ibid., 25.

of off-grid electrification identified were the use of isolated grids to achieve 25% of the electrification target and the use of standalone solar photovoltaic systems to connect another 20% of consumers.[45]

Isolated Mini grids

At least 6 isolated mini grids have been developed in Uganda as part of the rural electrification program. The details of these mini grids are shown in appendix 2. The two major sources of power generation on which the mini grids are based include diesel generation and micro hydro generation. The mini grids are located in different remote parts of the country, although the hydro generation based mini grids are all located in the south west which is rich in hydro generation potential.

The IREMP prioritises rural electrification through grid extensions and as such, mini grids have only been proposed in the medium to long term, based on diesel generation, for areas where the main grid is not anticipated to reach before then. The plan does not propose any mini grid projects in the short to medium term based on micro hydro or other renewable generation sources as these are seen as “developer led processes”.[46]

Standalone off grid electrification

The IREMP identifies solar photovoltaic systems as a viable technology choice for meeting electricity needs of remote off-grid communities. So far, this strategy has been implemented through acquisition of standalone solar systems for hospitals, district offices, schools and other small scale industries in off grid communities. It is estimated that about 20,000 solar systems of 50Wp capacity

[45] “Microsoft Word - Copy of REAStrategicPlan2006-2012-finaldraftMay06-060518[2] - Strategic Plan.pdf,” 9, accessed May 4, 2013, http://www.rea.or.ug/userfiles/Strategic%20Plan.pdf.
[46] “IREMP Masterplan Report Rev Jan 2009.doc,” n.d., viii.

have been installed through a subsidy scheme to meet the electricity needs of rural users.

Telecommunications within power infrastructure

Grid infrastructure

Telecommunications play a critical role in the operation and control of power grids, especially high voltage power lines and substations. As such, the transmission grid in Uganda today is equipped with optical fibre, which is used to operate and monitor the power transmission operations using SCADA.

The distribution grid however, does not have optical fibre installed. Communication on the distribution grid is implemented using wireless technology. In some cases, such as metering for industrial customers, commercial telecom networks are used to provide the communication services required, while UMEME also maintains a private wireless network. UMEME has plans of upgrading metering infrastructure on the distribution grid as well as other communication technology for substation control. It is likely that the installation of optical fibre will be carried out on parts of the distribution grid as part of these upgrades.

Off grid infrastructure

The widespread availability of wireless mobile coverage is being utilised to facilitate the development of off grid power solutions provided by micro utilities or energy service companies (ESCOs) in rural areas. In a project implemented by the Modi research group from Columbia University, existing wireless mobile services are used to provide an interface over which customers can access electricity on demand. Based on renewable generation, a village mini grid is installed to the premises of interested customers. Customers are then able to pay for electricity as and when required through mobile phone based applications and interfaces. The enterprise management system used to control the various generation sites also utilises the cellular network infrastructure.

Conclusion

Although the approach to electrification in Uganda today includes both grid and off grid infrastructure development, it seems that the focus is more on the development of the main electrical grid. This has several disadvantages as pointed out within the chapter, especially the fact that the rate of growth of the grid is unlikely to keep up with the rate of growth of demand. These disadvantages could potentially be mitigated by a balanced approach between grid and off grid infrastructure development.

Given the nascent state of development of Uganda's power infrastructure, the emergence of the smart grid should provide foresight for Uganda to leap frog traditional ways of building power systems and build from the start, power systems capable of delivering more reliable, greener power as will be required in the future.

Chapter 3 Telecommunications Network Infrastructure

Telecommunications networks have evolved from narrowband networks designed for the provision of basic voice telephony services to broadband networks that provide voice, data and video services. This section presents an overview of how telecom network infrastructure is changing with the evolution of technology used to provide telecom services to the end user. It describes the existing telecommunications infrastructure in Uganda, the plans for upgrading the infrastructure to provide broadband services and discusses how the infrastructure is powered.

An overview of the trends in telecom network infrastructure

At a macro level, a telecommunications network can be said to consist of four subcomponents: the core, backbone, access, and last mile networks. These components are connected through wire line or wireless technologies over large geographic distances and all require power as a critical input for their operation. As technology for the delivery of telecommunications services evolves to transfer larger amounts of traffic, containing more diverse types of information between end users, changes also occur at the physical infrastructure level. The trends in telecom network infrastructure for the backbone and access network are highlighted in this section.[47]

Backbone network

The backbone forms a crucial part of the network and is composed of high capacity links that interconnect core network elements and also carry aggregated traffic from various branches of the network onto the network core.[48]

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[47] Appendix 3 highlights the changes within the core network and last mile components of telecommunication network infrastructure.

[48] The scope of a network backbone may be local, national, regional or International depending on the diversity of branches or networks whose traffic it is designed to aggregate.

The transmission links that constitute the backbone network infrastructure are commonly built using wire line technology. Wire line technology is preferable for backbone links since, over time, it has proven to provide a more robust medium compared to wireless technology. Optical fibre is currently the dominant wire line technology used for backbone networks primarily because of its superior transmission and capacity capabilities compared to copper wire and coaxial cables.[49]

Despite the preference for optical fibre for the backbone network infrastructure, most developing countries, such as Uganda, currently have telecommunications networks that are predominantly built with wireless technology. This is as a result of leapfrogging the Public Switched Telephone Network (PSTN), which formed a base for wire line connectivity in developed countries, and achieving widespread telephone penetration through wireless cellular networks.

The use of wireless backbones was adequate in the era of voice telephony; but with the convergence of data, video and the Internet telecommunications networks carry significantly higher capacities of information that challenge the use of wireless technologies in backbone networks.[50]

Access network

The access network is the most “branched out” part of the network with links that are of lower capacity than backbone links and extend to connect end

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[49] “Technology for Telecommunications,” in *Telecommunications Networks*, Devices, Circuits, and Systems (CRC Press, 2011), 135, http://dx.doi.org/10.1201/b11361-5.

[50] “Information and Communications for Development 2009: Extending Reach and ... - World Bank - Google Books,” 51, accessed March 24, 2013, http://books.google.com/books?hl=en&lr=&id=_5DL8RXJUbgC&oi=fnd&pg=PA51&dq=Investment+models+and+regulatory+constraints+for+broadband+backbone+roll-out+in+selected+African+countries&ots=KB3fZsZO2I&sig=434AQvSDjzeuxJ35NzDdYwoVhfk#v=onepage&q&f=false.

users in diverse geographic locations. This traffic is then “backhauled” onto the backbone and then to the core network.[51]

Access network infrastructures in early telecommunications networks, such as the PSTN, were dominantly based on wire line technologies. However, the introduction of wireless technology and its relative ease of deployment to serve many users over large geographic areas, as well as enabling mobility through cellular networks, has made the use of wireless technology in the access network more prevalent than wire line, especially in developing countries. With increasing pressure to carry larger amounts of information, generations of wireless technologies have been deployed from the Advanced Mobile Phone System “AMPS,” also now known as “Generation 1” or “1G” wireless to 2G, through 3G up to 4G, and 5G is currently in early stages of development.

2G was the first generation of digital cellular technology developed mainly to support voice communication and Short Message Service (SMS). 2.5G, commonly known as General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE) started to integrate better data transfer capabilities up to a peak of 384kbps.[52] 3G[53] was then developed to support even higher data rates up to 200Mbps.[54]

Today, while 3G networks are widespread in developed countries and the focus is shifting to expanding 4G network coverage, developing countries are grappling with the transition from 2G to 3G. Some of the key challenges slowing

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[51] “Networks Fundamentals and Present Architectures,” in *Telecommunication Networks*, Devices, Circuits, and Systems (CRC Press, 2011), 35, http://dx.doi.org/10.1201/b11361-4.

[52] Ajay R. Mishra, *Fundamentals of Cellular Network Planning and Optimisation: 2G, 2.5G, 3G-- Evolution to 4G* (Chichester ; Hoboken, NJ: Wiley, 2004), 5.

[53] 3G technologies are defined under the ITU standard IMT 2000 and the following technologies in use today were approved as meeting this standard: HSPA, HSPA+, WiMAX

[54] “M.2023 - Spectrum Requirements for International Mobile Telecomunications-2000 (IMT-2000) - R-REP-M.2023-2000-PDF-E.pdf,” 12, accessed May 23, 2013, http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2023-2000-PDF-E.pdf; Brad Smith, “The Shift from 3G to 4G. (cover Story),” *Wireless Week* 14, no. 19 (February 2009): 1.

the transition include the lack of wire line backhaul infrastructure and the high cost of maintaining the wireless access network infrastructure.[55]

Given the structure of cellular telephone systems, the access network infrastructure, used to transmit wireless signals over a given area, is hosted at multiple locations, commonly called base stations, cell sites, or base transceiver stations (BTS). This infrastructure consists of towers or other antenna supports for radio and microwave antennas operating on pre-assigned frequencies. Each site also has power supply equipment and other passive infrastructure such as shelters with air-conditioning, depending on the location of the site.

The base station infrastructure of cellular network operators today typically supports "multiple generations of cellular technologies".[56] An upgrade from one generation of technology to another is achieved through the replacement or installation of additional antennas and radios to support the use of newer technologies. New base stations are thus built either to grow network coverage or to provide better network quality.[57]

Driven by growing end user demand for higher bandwidth, newer generations of wireless technology enable broadband transmission by supporting higher data rates in the access network for faster transfer of information. Although various wireless high speed data transfer access network technologies exist today, optical fibre technology provides superior performance characteristics and thus is preferred for connectivity within the access network. Combinations of wireless and optical fibre in "fibre to the tower", is a growing trend to support higher speeds for mobile broadband through wireless networks.[58] Wireless and optical fibre

[55] Mark Williams, *Broadband for Africa: Policy for Promoting the Development of Backbone Networks*, n.d., ii.
[56] JACK BROWNE, "Tracking Trends in Wireless Infrastructure.," *Microwaves & RF* 51, no. 10 (October 2012): 39–44.
[57] Ibid.

technologies in the broadband era are playing complimentary roles, where wireless enables mobility and wire line enables the delivery of higher data rates. However, the costs of laying optical fibre limit the extent to which it is used.

In an effort to minimise cell site acquisition costs and increase operational efficiency, telecom network operators are also influencing trends in access network infrastructure. Newer generations of base station equipment are becoming smaller in size with more flexible installation options and requiring lower amounts of power to operate.

Figure 4: Power consumption comparison between 2G and 3G base stations[59]

	Older	Newer
Small Capacity BTS	1.6 kW	0.8 kW
Medium Capacity BTS	3.4 kW	1.3 kW
Large Capacity BTS	5.4 kW	3.2 kW

Source: GSMA

Lastly, driven by the need to increase the efficient use of available spectrum, a new trend for wireless access networks is the shift from "macro cells" that span kilometres, to 'small cells' that provide coverage over less than a kilometre, as in a building . The use of small cells enables increased capacity to be delivered to the end user with better quality reception, while improving spectrum efficiency for the provider.[60]

The status of Telecommunications Infrastructure in Uganda

The penetration of telecommunications services in Uganda has experienced steady growth over the last six years. Phone service penetration has grown from 6% in 2005 to 46% in 2012; while Internet penetration, within the same period has

[59] Mary Roach and Charlotte Ward, *Harnessing the Full Potential of Mobile for Off Grid Energy*, Community Power from Mobile (GSMA, December 2011), 13.
[60] BROWNE, "Tracking Trends in Wireless Infrastructure."

more than tripled, growing from below 5% to 16%.[61] This growth has been enabled by widespread deployment of cellular wireless infrastructure throughout the country with limited wire line infrastructure.

Commercial telecom network operators' Infrastructure

Wireless technologies are used to deliver most voice, data, Internet and broadband services in Uganda today.[62] As such, the backbone and access networks are dominantly built with wireless technology. Currently, due to the growing significance of broadband, most operators are swapping out the wireless backbone infrastructure with optical fibre capable of supporting larger data capacities. There is an estimated 3000 km of optical fibre that has been rolled out by telecom network providers in Uganda mainly in between major towns and within Kampala.

The access networks are still primarily made up of wireless links supported by base station infrastructure. It is estimated that at least 3000 GSM base stations exist in the country[63], providing GSM 2G network coverage to 75% of the population and covering 65% of the geographical area of the country.[64] The telecom network operators are upgrading this network infrastructure to provide broadband services through the deployment of a variety of broadband wireless access technologies shown in appendix 4.

The network infrastructure rolled out by telecom network providers has tended to be concentrated in the urban areas and this trend is continuing to grow with the deployment of broadband services and infrastructure. Network infrastructure in most rural areas has been rolled out partly in fulfilment of

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[61] "Annual Post and Telecommunications Market Review - 2010 11," 23, accessed April 19, 2013, http://ucc.co.ug/files/downloads/2010%2011%20Annual%20Post%20and%20Telecommunications%20Market%20Review%20141111.pdf.

[62] "UCC Annual Market Review 2011-12.pdf."

[63] "Powering Telecoms: East Africa Market Analysis," 9.

[64] Ibid., 8; "Communications in Uganda," accessed April 19, 2013, https://www.itu.int/net/itunews/issues/2009/06/31.aspx; "Uganda | Data," accessed April 23, 2013, http://data.worldbank.org/country/uganda.

regulatory obligations and also due to increasing competition in urban areas, where new entrants are deploying service and thus forcing operators to grow network coverage and subscriber numbers in search of new revenues. Despite the fact that there is reasonable access to basic telecom services such as telephony in rural areas, the challenge of providing Internet and broadband services to these areas remains.

Government facilitated infrastructure

The Rural Communications Development Fund

The government in 2003 established the Rural Communications Development Fund (RCDF), to facilitate the extension of network infrastructure into rural areas that were underserved by commercial providers, so as to increase equitable access to communication services.[65]

Under the guidance of the RCDF Policy of 2001, in the period 2003 – 2009, the RCDF has contributed to the establishment of infrastructure, through which rural communities can access telecom services, in all districts of the country. Operating through a Public Private Partnership (PPP) model, the RCDF has subsidised the establishment of telecommunications infrastructure in three ways:[66]

(i) Extension of commercial provider network facilities

Telecom network providers bid for subsidies to extend voice and Internet services to underserved areas. The subsidy goes towards the construction of base station sites, which may be based on GSM or any other technology, in order to provide voice and Internet services. These sites are referred to under the RCDF programme areas as GSM Voice sites or Internet Points of Presence (POPs)

[65] "RCDF POLICY 2009 2010 – 2014 - RCDF_Policy_2011_2015.pdf," 3.
[66] "About RCDF," accessed February 27, 2013, http://www.ucc.co.ug/data/smenu/25/1/About%20RCDF.html.

(ii) Establishment of shared points of access to service

Despite the fact that network infrastructure and services were available in some rural areas, the population did not have the terminal user equipment required to access services. As such, in conjunction with private entrepreneurs, the RCDF facilitated the establishment of shared access points such as payphones, Internet cafes and Multi-purpose Community Tele-centers (MCT).

(iii) Establishing connectivity and provision of ICT terminal equipment to government facilities such as hospitals, schools and district offices.

Appendix 5 summarises the infrastructure rolled out by the RCDF during the period 2003 – 2010.

The unreliable and lack of electricity in rural areas was pointed out as a key challenge by RCDF project beneficiaries and telecom network operators, during the policy review process for the RCDF 2003 – 2009 policy.[67] Despite the fact that the challenge of electricity was subsequently highlighted as one of the areas that need to be tackled by the new RCDF policy, the new RCDF policy does not contain any specific actions to address the issue. The policy however, does indicate the need to promote the use of renewable energy technologies for powering ICT as well as the need to increase collaboration and harmonisation with other government programs, although the collaboration seems to be targeted at sectors on application level, such as health and education, excluding collaborations at the infrastructural level.[68]

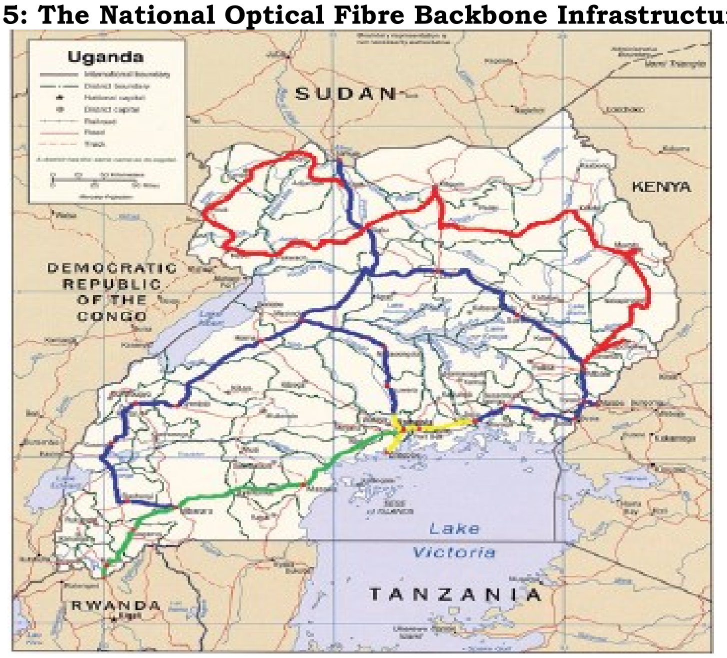
[67] "RCDF POLICY 2009 2010 – 2014 - RCDF_Policy_2011_2015.pdf," 19.
[68] Ibid., 26.

The National Optical Fibre backbone Infrastructure

The government of Uganda plans to leverage broadband to improve governance and delivery of public services to Ugandans.[69] To realise this goal, a national optical fibre backbone network, planned to span 1536.39km across the country, is being built to enable high speed data transmission among all major towns and to connect all government ministries and departments.[70]

The fibre optic backbone infrastructure was planned to be rolled out in four phases and was initially expected to be launched in 2010. However, due to various challenges and delays experienced in the construction of the network, the first and second phase were complete as at the end of 2012, and it is hoped that construction of the third phase will begin in 2013.[71]

Figure 5: The National Optical Fibre Backbone Infrastructure



Source; NITA – U

In light of the fact that telecom service providers are also laying optical fibre to improve telecom service delivery, specifically broadband, to various geographical

[69] "National Development Plan -Uganda.pdf."
[70] "NITAU NBI/EGI Project," accessed March 5, 2013, http://www.nita.go.ug/new/index.php/projects/nbiegi-project.
[71] "E-governance Project Drags on - Prosper - Monitor.co.ug," accessed April 30, 2013, http://www.monitor.co.ug/Business/Prosper/E-governance-project-drags-on/-/688616/1761984/-/7pedn8z/-/index.html.

areas within the country, the government plans to harmonise the rollout of optical fibre infrastructure with the private sector so as to ensure that broadband service is available throughout the country.[72]

End user equipment

Telecom network subscribers are able access a range of services including voice telephony, multimedia messaging services and in major towns specifically the capital city Kampala, data, Internet and broadband services are available. The majority of subscribers in the urban areas access services through personal mobile devices while in the rural areas, use of shared access points such as public payphones, multipurpose community tele-centers, Internet cafes, schools and district administrative offices is dominant.[73]The growing trend however is towards the use of personal devices.

Powering telecom infrastructure in Uganda

Electricity is a vital input for the provision and use of telecom services. In Uganda, the reach of the electric grid is limited and even where power is supplied by the grid, it is highly unreliable.[74] Despite this limitation, wireless telecom infrastructure is widespread within the country, even in areas without grid power. Innovative solutions have been devised to provide power for the operation of wireless telecom infrastructure and end user terminals, especially in rural areas of the country. A challenge however still remains as the cost of powering the wireless telecom infrastructure is high, impacting affordability of services. Usage of telecom services is also limited since power availability to operate end user terminals is constrained.[75]

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[72] "NITAU NBI/EGI Project."
[73] Patrick Masambu, "10 Year Sector Overview," 2009, 15.
[74] "Powering Telecoms: East Africa Market Analysis."
[75] Kivunike –Universal access study in Uganda

Power for wireless base stations

Wireless base stations require uninterrupted power supply in order to operate. Although 59% of base stations in Uganda are connected to the main electric grid, a large proportion (40%) of these sites has unreliable power supply.[76] As such, telecom operators have to install diesel generators at these sites in addition to the off-grid sites which by default rely on diesel generators as their sole source of power.

The use of diesel generators to power base stations is quite costly and constitutes over 60% of the operational cost for base stations with diesel generators.[77] This situation has led telecom operators to seek solutions to reduce the cost of powering wireless infrastructure.

One such solution is the combination of renewable power generation with existing diesel generators to create hybrid powered sites.[78] Hybrid sites are able to reduce costs by decreasing the amount of time the generator is used to provide power, as such, reducing the operational cost of operating the base station in the long term. Most hybrid sites are based on solar energy, however, the significant capital costs required to install solar power have challenged the widespread deployment of this solution. Only 3% of the base stations in Uganda are currently powered by a solar hybrid power solution.

Other challenges faced in powering base stations include the theft of diesel from generators both by maintenance staff and surrounding communities, theft of solar panels and difficulty in extending grid power to base stations due the location of base stations at a long distance from existing grid infrastructure and challenges in acquiring rights of way for extending power lines.[79]

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[76] An on-grid base station site was considered to have unreliable power supply if it experienced more than 6 hours of power outage per day
[77] "Powering Telecoms: East Africa Market Analysis," 11.
[78] Ibid., 13.
[79] Ibid.

Power for end user equipment or terminals

The availability of power affects users of telecom services differently depending on how they access services. Urban users have better access to electricity compared to rural users and as such, the major challenges for end users are faced by rural users.

Urban users access services through personal devices which they are usually able to charge within their homes or places of work where there is likely to be a connection to grid power. For the urban poor, who may not have easy access to power, there is an abundance of phone charging stations where they can leave their phones to be charged.

In the rural areas, access to telecom services is dominantly through shared devices or access points such as multipurpose tele-centres, schools and Internet cafes. Power is usually available in town centres where people come to trade, far away from their homes. Shared access points are also located in these town centres where other infrastructure such as local government offices, hospitals or health centres and some schools are located. Given that power from the grid is highly unreliable in these town centres of rural areas, many businesses have opted to acquire standalone sources of power, especially solar panels, as these are able to meet the requirements to charge and operate ICT equipment. ICT facilities set up by the RCDF also usually have standalone power sources –solar panels, to power the ICT equipment.

For rural individuals with personal devices, various innovative solutions are emerging to meet their needs for power. The operation of phone charging stations is an emerging rural enterprise area coming up to meet the power needs of rural ICT users. Charging stations are commonly based on solar PV systems or power storage systems in form of batteries that are charged in the town centres and transferred to the remote locations where power is required.[80]

Telecom service providers along with other entrepreneurs and NGOs are also making an effort to solve the power needs for users. Some notable potential solutions that have been tried include provision of solar powered handsets, inclusion of phone charging systems within solar lanterns, battery charging systems that can be recharged using bicycles or solar panels as well as use of excess power from wireless base stations.[81]

Figure 6: Phone charging solutions in rural areas

Source: GVEP International

Conclusion

The lack of available, reliable electricity in Uganda is inhibiting the provision and use of telecom services in the country. As telecommunications services, including broadband proliferate and become a key means of access to public services for Ugandans, there is an increasing need to solve the power scarcity, especially for rural users.

It is also clear that innovation to provide power for provision and use of telecommunication services is having an influence on the electrification of rural

[80] "Microsoft Word - Phone Charging Businesses Report with GSMA V1 2 - Phone_charging_businesses_report_with_gsma_final_for_web_0.pdf," accessed May 13, 2013, http://www.gvepinternational.org/sites/default/files/phone_charging_businesses_report_with_gsma_final_for_web_0.pdf.
[81] Ibid.

areas. As such, the exploration of solutions where power can be jointly supplied with telecom services is required.

Chapter 4 Joint Deployment of Power and Telecommunications Infrastructure

Power and telecommunications networks have traditionally been deployed by separate entities using separate network infrastructures to provide either power or telecommunications service to end users. However, as discussed in Chapters 2 & 3, each separate power or telecommunications network actually includes aspects of the other. Electrical power is necessary for the operation of telecommunications equipment, and telecommunications services are utilised to provide key “flow and use” information in power networks.

This chapter draws on experiences from countries where the use of telecommunications infrastructure in the power networks and power infrastructure in the telecommunications networks is resulting in the sharing of a single infrastructure to provide both power and telecommunications services. Specifically, it looks at experiences in Kenya, India, the UK and the USA and identifies, based on existing and planned deployments for power and telecommunications infrastructure, where the opportunities for joint deployment in Uganda exist. .

Definition of Joint deployment

Joint deployment in this paper refers to the sharing of infrastructure to facilitate the simultaneous provision of both power and telecom services. While power network infrastructure contains components for communication and telecom network infrastructure contains power network components, these facilities are meant for the provision of a service internally to the network. Within this context, joint deployment is used to refer to the situation where these components that serve an internal purpose for the respective network, may be shared to provide the same service to an external party.

The motivation for joint deployment in Uganda

A key priority for Uganda as a developing country is to meet the Millenium Development Goals (MDG) so as to enable social economic development for Uganda's citizens. Broadband, similar to electricity, is an enabler for these goals to be achieved. However, the provision and optimal utility of broadband is unlikely to be achieved without good access to electricity.

The existing rollout of power and telecom networks (in Uganda?) has resulted in a situation where some areas have both power and telecom services, some areas have either power or telecom services but not both, and some areas have neither of these services. Statistically, it is known that more Ugandans have access to telecom services than to electricity

Some questions therefore arise in relation to infrastructure development for Uganda, including: (1) Can future infrastructure for power and telecom networks in Uganda be rolled out jointly? And (2) can the power, used to power telecom network infrastructure, support other activities within off-grid communities? The following section, based on case studies and a review of the current literature on this topic, seeks answers to these questions by examining how joint deployment of power and telecom networks has been carried out in other places of the world.

Types of Joint deployment

Infrastructure sharing is not new in the power and telecommunications industries; however, it is taking on different diverse forms as [power and telecom services] network infrastructures evolve. Infrastructure sharing has changed from sharing with other providers within the same industry to sharing with providers outside the industry offering different services. This increases the occurrence of joint deployments between the power and telecom industries.

Joint deployment based on the electric grid

The growing need for high reliability and bandwidth to monitor and control the electric grid using technology such as SCADA, favoured the continued development and use of optical fibre for power system communications[82]. The excess bandwidth available in optical fibre deployed for power system control has led to the growth of joint deployment through the development of techniques for the deployment and use of optical fibre along the electrical grid. These are described in the following sections.

Optical fibre integrated with power lines

Although power companies today also utilise wireless telecommunications technology for coordination and control of power system operations, optical fibre has emerged as the preferred technology. Joint deployments of power and telecom wire line infrastructure is thus dominantly based on optical fibre technology. The following table summarises the technologies used today for the joint deployment of power and telecom infrastructure in electrical grids.

[82] "Bits of Power - The Involvement of Municipal Electric Utilities in Broadband Services.pdf," n.d.

Table 1: Technologies for deploying optical fibre with power lines[83]

Technology	**Description**	**Advantages**	**Disadvantages**
Optical Ground Wire (OPGW) or Optical Phase Conductor (OPPC)	optical fibre cable is embedded within the overhead phase or earth conductors	Mature technology Single installation of power lines and optical fibre	Maintenance affects both communication and power network
Wrapped Cable	Optical fibre is helically wrapped around either phase or earth conductor.	Can be installed over existing low voltage power lines	Risk of failure when used on high voltage lines above 150kV
All Dielectric Self Supporting cable	fully insulated and reinforced optical fibre that is self-supporting	Optical fibre is separate from power conductors	Suitability for use varies depending on load and clearance Safety concerns for maintenance workers

Source: Adapted from Tom Tamarkin

Passive infrastructure within power networks

The passive infrastructure used to deploy power lines, either overhead or underground, is similar to that used to deploy wire line telecommunications infrastructure. For overhead deployment, power lines are supported by poles, which may be of different heights and sizes depending on the voltage of the lines running along them. For underground deployments, insulated power lines are deployed inside ducts or conduits which provide extra protection for the power cables.

As a result of the similarity in passive infrastructure used for the deployment of wire line telecommunications infrastructure, utility poles as they are

[83] "Using Overhead Distribution Lines to Carry Fibre Optic Cables | Beyond Broadband," accessed March 6, 2013, http://www.beyondbroadband.coop/kb/using-overhead-distribution-lines-carry-fibre-optic-cables.; M Ostendorp, *Fiber Optic Cables in Overhead Transmission Corridors*, n.d.

commonly known, have been used widely in the UK and USA for attachment of wire line telecommunications infrastructure. Similarly, underground electrical conduits have also been shared to facilitate the deployment of telecommunications wire lines[84]. The sharing of passive infrastructure between telecommunications and power networks is regaining significance with the advent of smart grids and in the race to develop broadband technologies such as Fibre to the Home (FTTH).

Joint deployment in wireless access networks

Infrastructure sharing in wireless networks has occurred as a result of fast changing technology, requiring network operators to deploy and operate multiple generations of wireless technology, i.e. 2G and 3G simultaneously, in order to meet customer demands. Infrastructure sharing has thus provided a solution for network operators to meet network rollout demands, as it provides a faster means of rolling out the network in addition to lowering the costs of building and operating the network[85].

Various forms of infrastructure sharing exist for different levels of maturity within the respective telecom industry. Starting with the most basic form and advancing, the forms of sharing include: (1) site and passive Radio Access Network sharing, where the cell site, tower, power or shelter equipment may be shared but separate radio equipment is maintained by each operator, (2) Shared Active Radio Access network sharing – where the operators share the passive infrastructure as well as the active radio access network equipment and (3) full network sharing – where the radio access and core network are shared and the operators are only

[84] T. Randolph Beard, George S. Ford, and Lawrence J Spiwak, "The Pricing of Pole Attachments: Implications and Recommendations," *Review of Network Economics* 9, no. 3 (January 29, 2010), doi:10.2202/1446-9022.1192.
[85] C. Beckman and G. Smith, "Shared Networks: Making Wireless Communication Affordable," *IEEE Wireless Communications* 12, no. 2 (2005): 78–85, doi:10.1109/MWC.2005.1421931.

differentiated by brand or services provided[86]. As infrastructure sharing advances through these phases, the opportunity for joint deployment increases as the network infrastructure is typically outsourced to an infrastructure provider such that the telecom company can concentrate on other service aspects, aside rolling out and maintaining network infrastructure.

In most developed countries, wireless communication technology became widespread after wired telecom and power infrastructure had been ubiquitously deployed, and as such there is little motivation for joint deployment based on wireless infrastructure. This is however not true for developing countries where in most areas, wireless telecommunications infrastructure has preceded the existence of power infrastructure. As a result, the existence of grid and off-grid powered base stations in communities without access to power and the growing demand for power within these communities driven by the use of cellular phones, has resulted in base station infrastructure being looked at as a potential source of power for off-grid communities.

The earliest form of sharing power from base stations involved the charging of batteries at the base station and then transferring the batteries to another point within the community where users could come to access the power through the services offered. The concept, however, has evolved and two ways in which power from base stations can contribute to providing power to off-grid communities are emerging from the literature and are discussed below.[87]

Central Community Power Hub/Sharing point

A "Central Community Power Hubs/Sharing point" is the simplest form in which power from the base station is shared with surrounding communities. In this

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[86] Ibid.; T. Frisanco et al., "Infrastructure Sharing and Shared Operations for Mobile Network Operators From a Deployment and Operations View," in *IEEE Network Operations and Management Symposium, 2008. NOMS 2008*, 2008, 129–136, doi:10.1109/NOMS.2008.4575126.

[87] Roach and Charlotte Ward, *Harnessing the Full Potential of Mobile for Off Grid Energy*.

model, the base station power source is the sole supplier of power, and a single connection or low voltage distribution line is constructed from the base station to a central point within the community. The central point may be in the form of a "social infrastructure," such as a water pump, school or clinic, while in other cases it is simply a power station or "charging booth" run by a local entrepreneur.

The power available to the community in this model is the excess power not consumed by the base station during operation. The base stations from which excess power is available are hybrid powered from solar, wind and diesel generators. The activities supported by this model have been limited to low power applications, such as the charging of cell phones, batteries and other electronics, since the power generation source is dimensioned for the base station load only. The amount of power consumed by the community is controlled by the base station operator such that the operation of the base station is not compromised by the use of electricity within the community.

The Community Mini Grid

In this model, the base station infrastructure is leveraged as part of a "community mini grid." The base station infrastructure plays different roles by either: (1) providing a location where the infrastructure for the community's power generation is co-located with the base station and may share part of the power equipment with that base station, or (2) acting as an 'anchor load' to make energy supplied, from another power generation source, economically viable to the rest of the community.

The mini grid model typically does not rely on the excess power generated from the base station. The main source of power generation is located within the community and based on a renewable source of generation, such as solar or bio mass, combined with either diesel generation or battery storage for backup purposes. The power generated is distributed to various households or social infrastructure within the community, depending on the capacity of the power generation source.

The role played by the base station infrastructure in this model varies with the ownership of the base station and community power generation infrastructure. In the case where the base station was owned by the same party that owned the community power infrastructure, it was possible to co-locate the community power generation infrastructure with the base station. Where ownership of the base station was not the same as that of the community power infrastructure, the base station was merely a load connected to the mini grid.

The mini grid model is capable of providing more power for more diverse uses to the community since the power generation source is not limited to the requirements of the base station. Despite the fact that the power infrastructure of the base station is not the main power source for the mini grid, the base station infrastructure within the community still plays a strategic role in enabling the existence of the community mini grid.

Mapping out the opportunity for joint deployment in Uganda

With only 12% electrification and 47% penetration of telephony, it can be said that the country is at a nascent stage in developing infrastructure for power and telecommunications. While some areas in the country enjoy the latest technology available worldwide for communications, others struggle to access basic communication services. A similar situation exists in terms of access to electricity. Joint deployment provides an opportunity to extend both telecommunications and power infrastructure potentially yielding better utility from the existence of either service. It is therefore important to assess where and how joint deployment can play a role in further development of infrastructure, so as to facilitate the achievement of Uganda’s development goals.

A gap analysis of the existing infrastructure

In order to identify areas in Uganda where joint deployment will be relevant, a gap analysis of the existing infrastructure is carried out below. Four categories of areas are identified based on the nature of power and telecommunications services available within selected towns. An estimated infrastructure distribution is then suggested and is used to define gaps in infrastructure for the four areas. Based upon the defined gaps, the potential for joint deployment is then discussed for each of the areas.

Identifying the areas

Category 1- Urban: This category maps to areas such as Kampala, Mukono, Entebbe, Mbarara, Mbale and Gulu. Major businesses, industries and social infrastructure such as paved roads is developed to a good extent and the majority of the formally employed population lives in these areas.

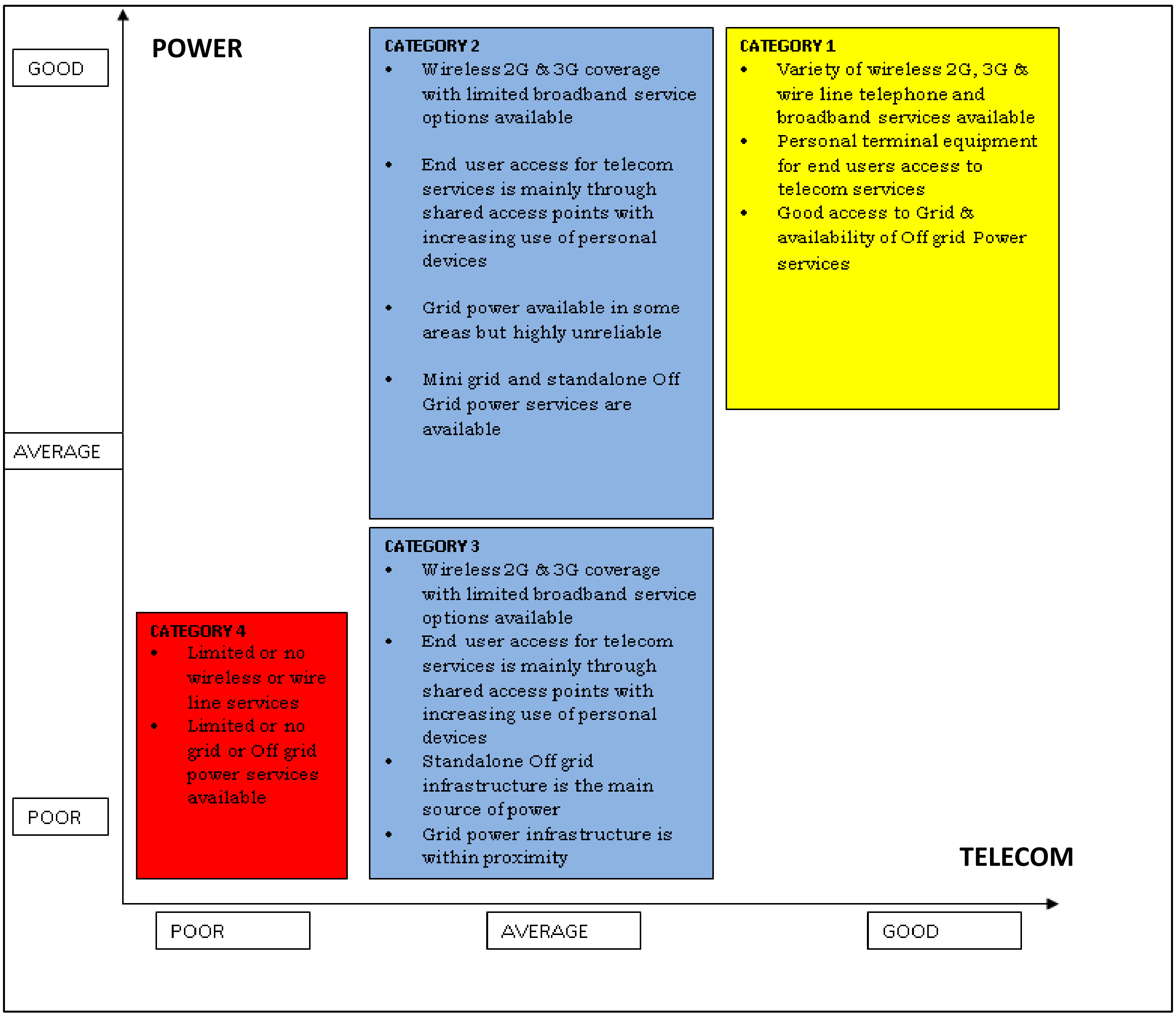
Category 2 – Peri-Urban: This category maps to towns such as Jinja, Masaka, Wakiso, Soroti, Lira, Arua and Iganga that are high population centres and are in close proximity to either Kampala or other major towns. In these areas, the economic activity is driven by trade - small and medium scale trading enterprises and agriculture and there is some social infrastructure with limited paved roads.

Category 3 – Rural: This category maps to areas that are far separated (geographically) from the major towns where there is an economic activity such as mining, fishing or a key tourist attraction such as a game reserve that attracts people to visit or settle in the area. The social infrastructure is centred around these key economic activities. Examples of such towns in rural Uganda include Kasese, Fort Portal, Hoima, Tororo, Kitgum and Kalangala.

Category 4 – Remote: This category maps to areas that are far from existing key economic centres of activity and social infrastructure and could be referred to as remote. They are most likely to be located in districts where category 2 and 3 towns are found, although they may also exist in some districts with towns in category 1.

The following figure summarises the current nature of the availability of power and telecom services within these four categories of areas so as to provide a basis for mapping opportunities for joint deployment

Figure 7: Categorisation of areas based on Power and telecommunication services



Source: author

Defining the Gaps

Gaps in Telecommunications Infrastructure

A distribution for the population estimated within each category defined above is developed as follows; since it is known that the urban population is 5M, this is all assigned to category 1. The remaining 29 million is distributed among category 2, 3 and 4 with a bias for larger population in the rural areas.

The telecommunication services available are categorised into fixed and wired broadband, mobile broadband, narrowband Internet and basic telephony services. The gap in infrastructure is defined based on the availability, access to and quality of services available within each category. By taking category 1 as a reference, a gap **X** is defined for other categories, where **X** denotes the lack of or difference in infrastructure for provision or access to the given telecom service, at a level comparable to that of category 1. √**X** is also used to define a partial gap where infrastructure may be available within limited areas of the town and the quality of the services is poorer than those available in category 1.

Given that quality of service generally deteriorates as movement occurs from urban to rural areas, it is assumed that the infrastructure availability, access and thus telephone penetration rates also decrease. The much lower penetration rates could be attributed to the use of shared means to access services and as such, even network infrastructure for service provision is not widespread within the area. Assuming that 80% of the population in category 1 subscribes to telecom services, the percentage of people subscribed to telecom services for categories 2 and 3 is estimated to be lower by 20%, resulting in a penetration of 27% for category 4.

Table 2: Gaps in telecommunication infrastructure

Category	**Population (millions)**	**% population**	**Assumed penetration**	**No of subscribers (m)**	**Fixed or wired**	**Mobile BB 3G**	**Narrow Band Internet**	**Basic voice telephony**	**GAP**
1	5	15	80%	4	√	√	√	√	**0**
2	8	26	60%	5	**X**	√ **X**	√	√	**1.5X**
3	10	29	40%	4	**X**	√**X**	√**X**	√	**2X**
4	11	32	27%	3	**X**	**X**	X	√**X**	**3.5X**

Source: Author

The derived gaps suggest that category 3 and 4 are the farthest away from category 1 in terms of infrastructure deployment to provide the various categories of telecom services specified.

Gaps in Power Infrastructure

Using the same population distribution estimated above in the telecom infrastructure section, the available installed generation capacity supplying the existing electric grid in Uganda and installed off grid capacity is used to derive the gaps in power infrastructure amongst the four categories. The table below shows the suggested power infrastructure gaps.

Table 3: Gaps in Power infrastructure

Category	% population	Population (millions)	% electrificati	No. of Consumers (millions)	Installed Generation Capacity	Capacity per consumer	GAP
1	15	5	20	1	370[88]	0.4	N/A
2	26	8	9	0.7	186	0.2	2
3	29	10	2.5	0.25	2	0.08	5
4	32	11	2.5	0.25	2	0.08	5

Source: Author

It is known that for estimated grid electrification rate at 13%, only about 30% of the population in the urban and peri urban areas has access to electricity. The number of consumers in categories 1 and 2 are thus derived. For categories 3 and 4, based on the estimate that 5% of the rural population now has access to electricity, the figure is evenly split between the two categories. The installed generation capacity is then used to determine the capacity per consumer.

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[88] Since two thirds of the power generated is consumed within urban areas, two thirds of the installed generation capacity is assigned to category 1 and the other third to category 2, given that category 3 and 4 have no existing electric grid infrastructure. The same proportions are used to allocate the grid connected consumers in category 1 and 2

The power gap for each category is defined as the multiplying factor required to raise the installed power capacity per consumer to the same level as that for consumers in Category 1. Again, it is seen that category 3 and 4 have the largest gaps compared to category 1.

Relating the gaps to the potential for joint deployment

Since the provision and use of telecommunications services is dependent on the availability of power, the potential for joint deployment is likely to be driven by the capability for joint deployment to ease challenges faced in the provision and use of telecom services. The table below thus highlights the challenges related to telecommunications infrastructure operation in the four categories and relates the gaps in power and telecommunications infrastructure to the potential for joint deployment.

Table 4: The potential for joint deployment based on challenges of existing telecom infrastructure

Category	Telecom gap	Power Gap	Challenges	Potential for Joint deployment
1	N/A	N/A	It is assumed that there are no challenges in category 1, but in reality there are some such as unreliable grid power.	LOW
2	SMALL	MEDIUM	• Unreliable grid power • Difficulty in getting way leaves for extension of grid power to base station sites • High cost of running diesel generators to power access network base station sites • Theft of network components • Limited Backhaul capacity • Difficulty in powering end user personal devices and shared access points	MODERAT E

3	SMALL	LARGE	• High cost of operating diesel generators • Diesel and solar panel theft • Limited Backhaul capacity • Great difficulty in powering end user personal devices and shared access points	HIGH
4	LARGE	LARGE	• Same as Category 3 challenges	HIGH

Source: Author

High Potential

Categories 3 and 4 combined are inhabited by almost two thirds of Uganda's population, and yet, have the lowest levels of infrastructure deployed for power and telecommunications respectively. The potential for joint deployment in these areas is high, as they will be the focus for new infrastructure development aimed at increasing power and telecom coverage. Joint deployment can likely help to avoid creation of the challenges currently faced in operating telecommunication infrastructure in those areas.

Telecom network expansion in category 3 is likely to focus on enhancing the coverage of wireless 3G technologies while category 4 is likely to be the source of new coverage for basic telephony services.[89] Category 3 also has areas through which the national optical fibre backbone infrastructure will be passed. While some areas in category 3 will likely benefit from grid electrification according to the IREMP, dependng on their population densities and proximity to the existing electrical grid. Electrical infrastructure in category 4 is likely to be developed in the form of off grid infrastructure such as mini grids and standalone power.

[89] It is difficult to anticipate whether network operators will choose to first rollout older technologies for new network coverage or expansion and then upgrade to 3G in these remote areas or whether they will rollout 3G data technologies initially.

The independent developments of power and telecom infrastructure in these areas will likely to be facilitated to a great extent by the government. This creates the opportunity to implement the two forms of joint deployment identified.

Moderate Potential

For Category 2, joint deployment presents an opportunity to enhance services provided within the area. Commercial service providers have the opportunity to extend optical fibre over the existing electrical distribution grid infrastructure, to improve broadband services within the area. Despite the fact that some off grid base stations exist in this area; the proximity of the electrical grid decreases the motivation for development of mini grids that leverage the base station infrastructure. Joint deployment can however still occur if grid extension efforts to telecom sites integrate provision for connection of some locations within nearby off grid communities.

Low Potential

The potential for joint deployment in Category 1 is low as there is widespread deployment of independent telecom and power infrastructure already existing. It is highly unlikely that any joint deployment based on wireless base stations will occur however, there is an opportunity for operators to extend optical fibre infrastructure in the access network and for last mile connections, by leveraging the existing electrical grid infrastructure.

Challenges of Joint deployment

Coordination

The Ugandan Government is in control of development of the electric grid while the deployment of telecommunications infrastructure is controlled by commercial providers. For joint deployment to be effective, commercial providers need to know how the electric grid extension is planned to happen so as to avoid duplication of infrastructure where optical fibre capacity will be available. Joint deployment based on wireless access networks is also likely to be more successful in areas where the electric grid is not likely to be extended in the near future.

Risk of disruption

Joint deployment creates the risk that a single point of failure can create disruption of both power and telecommunications services. In certain cases, this could be a security risk or result in more loss than would occur if the infrastructure was deployed separately.

Security

Optical cable routes in some cases are kept secret for security purposes to prevent potential saboteurs. Installation with power lines exposes the communication network and can therefore become a potential security risk for a national (government) information network.

Nature of base stations

Joint deployment is feasible in the community hub model using base stations powered by renewable hybrid power solutions, which are more likely to generate excess power. The base stations also need to be in close proximity to the community as well as the other source of generation for the community mini grid model. These factors could limit the possibility of joint deployment on a large scale.

Conclusion

The different forms of joint deployment, based on the electric grid and wireless base stations, present an opportunity for joint deployment in Uganda, ideally for the deployment of new infrastructure but also in the form of incremental deployments based on existing infrastructure.

The opportunity is highest in rural areas where joint deployment could potentially ease the challenges faced in the provision and use of telecommunication services as a result of poor power infrastructure. For new infrastructure deployments, these challenges could be avoided altogether and the opportunity for faster rollout of modern communication and power infrastructure also exists, while areas with significant already deployed infrastructure can leverage joint deployment to provide better infrastructure for improved service provision. The following chapter examines how economies of scope could potentially influence the potential for joint deployment and whether economic incentives exist for the various stakeholders involved in infrastructure deployment for power and telecommunication, which could present further justification for joint deployment.

Although these technical options for joint deployment exist, government policy which plays a significant role in how and where infrastructure is deployed will be instrumental in promoting joint deployment, over the traditional independent deployments. The policy aspects related to joint deployment are therefore discussed in a later chapter.

Chapter 5 Economic Discussion of joint deployment

Despite the existence of technical options to implement joint deployment, as discussed in chapter 4, the implementation of these alternatives must make economic sense in order to be a viable option to independent infrastructure deployments. The possibility for joint deployment implementation is highest for new infrastructure development in rural and remote areas, where poor or no infrastructure for power and telecommunications currently exists.[90]In contrast, the likelihood for joint deployment appears to be lowest in urban areas which currently have good levels of power and telecommunications infrastructure deployed.

The economic incentives for joint deployment are examined in this section by investigating the existence of scope economies for the provision of both power and telecom services, as well as considering the motivation for the various government and private sector stakeholders, besides the accrual of scope economies.

The cost framework

Despite the current low levels of infrastructure penetration, it appears that the costs of independent infrastructure deployment, operation and maintenance are still rather high. Can joint deployment provide a lower cost alternative? Evaluation of costs is done by comparing the sum of estimated costs for independent deployment of power and telecom infrastructure with the estimated costs for deploying the two together. If the joint deployment costs are lower than the sum of the costs for the two independent deployments, it indicates the possibility of economies of scope.

The Indicative Rural Electrification Master Plan (IREMP) for the 5 – 10year period starting in 2009, based upon least cost comparison of electrification alternatives, suggests that the optimal solution for electrification in Uganda is likely

[90] These areas are represented by category 3 and 4 as described within the joint deployment section in chapter 4.

to be the hybrid development of both the centralised (grid) and decentralised (off grid) power infrastructure.[91] This is due to the fact that grid extension is not cost effective for areas located beyond a certain threshold distance, from the existing electric grid, depending on the nature of the demand (power usage and consumption) and population density for the different areas.[92] The two forms of joint deployment identified in chapter 4 align well with this approach to developing power infrastructure, since one form is based on the electric grid infrastructure and the other form is based on off grid power infrastructure for wireless base stations.

Investigating Economies of scope

Economies of scope are said to occur where the average cost of producing two products using a shared input is lower than the cost of producing the two products separately. The primary product may be referred to as the base product and the secondary product may be referred to as the incremental product.

The costs for joint deployment are thus analysed within two contexts; scenario 1 – the areas where the distribution grid extension is planned or likely to be feasible[93] and scenario 2 – areas where off –grid power alternatives are the anticipated solution for electrification. The tables below show estimated costs of joint deployment in comparison to independent deployments for power and telecom infrastructure for these two scenarios.

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[91] "IREMP Masterplan Report Rev Jan 2009.doc."

[92] Similarly, for telecommunications networks, the optimal infrastructure consists of both wired and wireless technology playing complimentary roles, as discussed in chapter 3, to deliver broadband services.

[93] The IREMP focuses on the development of the distribution grid since the transmission grid is deemed to be mature with no large changes likely to occur. It however takes into consideration different estimates for growth in transmission and also puts into consideration the anticipated growth in generation. "IREMP Masterplan Report Rev Jan 2009.doc," 31.

Scenario 1: Grid based joint deployment

Independent deployment = (Grid extension + Buried fibre) cost/km (USD)

Joint deployment = Cost/km of Grid extension with optical fibre using (OPGW)

Comparison at 11kV

Grid extension + Buried fibre installation cost = 15,000[94] + 29,000[95] =**44,000**

Grid extension with OPGW = **30, 000**[96]

Comparison at 33kV

Grid extension + Buried fibre installation cost = 28,000[97] + 29,000 =**57,000**

Grid extension with OPGW = **40,000**

For grid based joint deployment, the power infrastructure provides the base service and the telecommunications service is the incremental service. From the comparisons made above, it can be seen that the cost for joint deployment is less than the total cost for independent deployment of the infrastructure for the two services. This creates an opportunity for economies of scope to accrue for the power infrastructure provider.

Currently, power distribution grid extensions in Uganda are made using plain conductor wire, as it is deemed that the communication requirements at the distribution level can be met using cheaper wireless technologies, compared to dedicated fibre infrastructure. However, as discussed in chapter 2, the advantages of having advanced communication capabilities even at distribution level are likely to justify these costs in the near future, and as such, the added opportunity to accrue economies of scope by offering a service to telecommunications companies seems to provide sufficient cost justification to install optical fibre for new distribution grid extensions.

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[94] Ibid., 66.
[95] Estimates developed from National Backbone Infrastructure project for Uganda
[96] Expert information based on OPGW installation in Uganda
[97] "IREMP Masterplan Report Rev Jan 2009.doc," 66.

The deployment of power distribution grid infrastructure in Uganda is facilitated by various actors, and as such, the incentive for the cost advantage provided by joint deployment to be leveraged may vary depending on which actors are involved. This is discussed more in the incentives section, later in this chapter.

Scenario 2: Off Grid joint deployment

Table 5: Independent and joint deployment costs for off grid joint deployment

Independent deployment	Estimated initial cost/ unit (USD)	Notes
Base station with diesel generator	230,000 - 300,000[98]	Life time operational costs not included
Individual users with standalone solar PV or diesel generators	5,000 – 30,000 [99]	Cost range for powering individual peak loads of less than 50kW
Mini grid	150,000 – 220,000[100]	30kW peak load based on either diesel or solar PV panels
Joint deployment		
Hybrid Base station serving community Hub	250,000 - 300,000	Cost includes minimal distribution infrastructure to connect to hub
Hybrid Base station supporting village mini grid	380,000 - 520,000	20kW - 30kW peak load based on hybrid Solar and diesel generation, including distribution connections

Source: Adapted from IREMP and Alliance for Rural Electrification

For scenario 2, the telecommunications service is assumed to be the base and the power service is incremental. Since it is known that the lifetime operational cost for hybrid base stations is lower than that for diesel powered base stations, the analysis for economies of scope in this scenario is limited to the initial capital costs.

[98] Expert information based on installations in Uganda
[99] "IREMP Masterplan Report Rev Jan 2009.doc," 69.
[100] Ibid., 61.

The cost for joint deployment using the community hub model assumes that the same power generation facility installed to serve the base station load is used to serve the community. Although this option appears to be cost effective, resulting in economies of scope for the telecom provider, the solution is not scalable due to the limited excess power available and thus it is not sustainable in the long term. It is however adequate as a primer for places where literally no power infrastructure exists in close proximity of community settlements.

For the mini grid joint deployment model, the cost for development of additional power generation meant to serve the community is added to the cost for deployment of the wireless base station. It is assumed that the diesel generator is shared and solar generation is chosen due to its lower operational and maintenance costs compared to diesel generation, in the long term. No initial capital cost advantage accrues in this case due to the fact that the telecom infrastructure owner would have to meet a significantly higher initial capital cost and increased operational complexity to additionally provide power services.

Joint deployment in this case would only make sense if the Net Present Value (NPV) of the cash flows from the provision of the two services is higher than that from the provision of only the telecom service. Thus, although the business case for the telecom provider diversifying into the provision of power services might exist in the longer term, the growing trend, where telecom companies lease infrastructure from tower companies, shows that telecom providers have little interest in continuing to manage their own base station infrastructure and therefore probably not interested in taking on new challenges to provide power services.

Notwithstanding, there is still incentive for telecom providers to participate in the development of a community mini grid. The mini grid in this case would be developed and managed by emerging third party entities, referred to as Energy

Service Companies (ESCO). The incentives for the telecom providers and ESCOs to implement joint deployment are discussed in the following section.

Incentives for Joint deployment

Who should have incentive to jointly deploy infrastructure for power and telecoms?

The majority of infrastructure for power and telecommunications in rural areas of Uganda is deployed and operated by a combination of government and private sector resources through public private partnerships. However, purely government, private for profit and private non-profit initiatives for infrastructure development and maintenance also do exist. The table below identifies the stakeholders involved in infrastructure deployment and highlights their roles.

Table 3: Government and Private sector stakeholders and their roles

<table>
<tr><th colspan="2">Infrastructure</th><th>Sector</th><th>Actor</th><th>Funding source</th><th>Role</th></tr>
<tr><td rowspan="6">POWER</td><td rowspan="2">GRID</td><td>GOVT</td><td>REA</td><td>• Central govt.
• International Development Partners
• ERA Surplus
• 5% levy on bulk power purchase</td><td>Funds and supervises construction of distribution grid extensions in rural areas</td></tr>
<tr><td>Private</td><td>UMEME, FESL, KIL,PACMECS, BECS</td><td>• Private</td><td>Operate distribution grid infrastructure under concession agreements</td></tr>
<tr><td rowspan="4">OFF GRID</td><td rowspan="2">GOVT</td><td>UEDCL</td><td>• Central govt. allocation</td><td>Operates off grid infrastructure (diesel mini grids)</td></tr>
<tr><td>REA</td><td></td><td>Subsidises solar PV panels</td></tr>
<tr><td rowspan="2">Private</td><td>Rural hospitals & ESCOs</td><td>• Private
• REA loans</td><td>Own & operate private mini grids</td></tr>
<tr><td>IPPs</td><td>• Private</td><td>Licensed to develop unexploited generation sources</td></tr>
<tr><td rowspan="6">TELECOM</td><td rowspan="2">W IRED</td><td>GOVT</td><td>NITA</td><td>• Central govt.
• International devt. partners</td><td>Implementing the National Optical Backbone infrastructure rollout</td></tr>
<tr><td>Private</td><td>Telecom Network Operators (Telcos)</td><td>• Private</td><td>Developing own optical fibre backbone and access network infrastructure</td></tr>
<tr><td rowspan="4">WIRELESS</td><td>GOVT</td><td>RCDF</td><td>• 1% Universal access levy on service providers</td><td>Subsidises rollout of infrastructure in rural areas</td></tr>
<tr><td rowspan="3">Private</td><td>Telcos</td><td>• Private
• RCDF subsidies in rural areas</td><td>Rollout own wireless infrastructure for service provision</td></tr>
<tr><td>PowerCos</td><td>• Private</td><td>Maintain power infrastructure for Telco wireless base stations</td></tr>
<tr><td>TowerCos</td><td>• Private</td><td>Own and lease passive tower infrastructure to Telcos</td></tr>
</table>

Source: Author

Incentives for Grid based joint deployment

In the case of grid based joint deployment, the government should have the highest incentive for implementing joint deployment since the accrual of scope economies would free up resources for greater infrastructure deployment. However, given the fact that each sector independently finds the funds to be put towards specific infrastructure development projects, the focus seems to be on maximising efficiency within each sector and not across the range of services being provided by the government. Thus although, the government should have incentive to implement joint deployment, it appears as though it doesn't due to this sector specific focus.

The private sector concessionaires who operate power distribution network infrastructure should also have incentive to carry out joint deployment dependent upon the terms of their concessions. UMEME holds a 20 year concession agreement with UEDCL and operates the largest part of the power distribution network. It is allowed an annual return on investment of 20% on investments made in fixed assets as approved by the regulator.[101] This could potentially serve as both an incentive and disincentive for joint deployment, depending on whether such deployments would be considered necessary and thus justifiable. The terms of the other concessionaires whose agreements are with REA to operate significantly smaller grid extensions in rural areas have not been found, however each concessionaire is assigned an exclusive region in which to operate.

In some countries, telecommunications companies have partnered with electric utilities in order to overlay existing power distribution networks with optical fibre. This has not happened in Uganda as most telecom network operators installing optical fibre backbones and access network infrastructure in areas with

[101] Umeme Annual Report 2012, 45

existing power grid infrastructure are deploying their network infrastructure independently.

It is as such likely that there is no enabling environment for them to access and leverage the existing power grid infrastructure, despite the cost advantage of joint deployment.

Incentives for off - grid joint deployment

Similar to the case for grid based joint deployment, the government should have incentive to foster joint deployment since it subsidises the rollout of off grid power solutions as well as telecom infrastructure in rural areas. In the telecoms sector, the government facilitates infrastructure deployment in rural areas through subsidies to private providers and a similar trend is observed for off-grid power deployment within the power sector.[102] Given that telecommunications infrastructure is developing at a much faster rate than power infrastructure, it would thus be advantageous if this can be leveraged to improve electrification in off grid remote areas. Again, since the subsidies are separately awarded within different sectors, it appears that the separated jurisdiction of government undermines the incentive to foster joint deployment where it would be in the economic and social interest of the population.

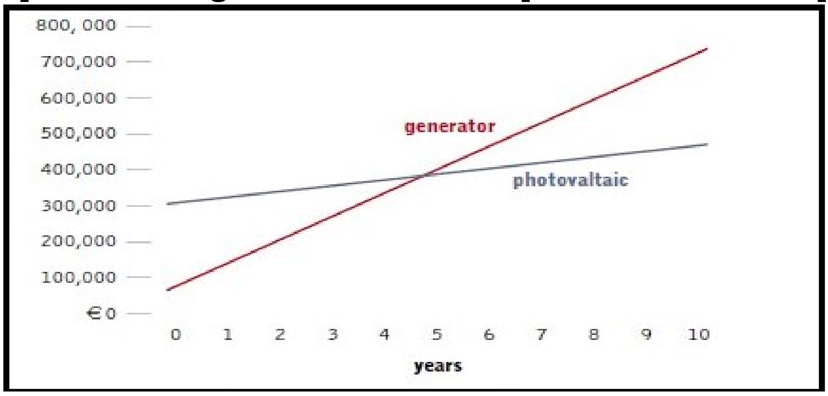
Although telecom providers are likely to be willing to implement joint deployment based on the community hub model, they also likely have incentive to see the mini grid model developed by ESCOs. For the telecom provider, the emergence of ESCOs in off grid areas presents the opportunity to overcome the operational challenges faced in powering base station infrastructure in off grid areas. These challenges, discussed in chapter 3, include the rising cost of diesel and insecurity or fuel theft from base station sites. In a bid to bring under control

[102] The construction of grid extensions is financed by the government and the private companies come in to operate and provide services under the concession agreements.

high operational costs of maintaining base station infrastructure and raise funds to finance upgrade of infrastructure to provide mobile broadband services, telecom network operators are selling and leasing back their tower infrastructure from tower companies.[103]

This trend creates an even greater opportunity for ESCOs to develop as the tower companies will likely promote infrastructure sharing amongst service providers of telecommunication services, and will likely outsource the power services where and if possible. ESCOs have preferred to develop renewable sources of generation as suited for the different local environments and as such, have the potential to offer lower costs of power for base station infrastructure in the long term.[104]

Figure 8: Comparison of long term cost of diesel operated and solar PV power supply



Source: Alliance for Rural Electrification

Telecom operators thus have the incentive to see joint deployment become a real option for powering base station infrastructure, however, the power and telecom policy and regulatory environments must be able to nurture this upcoming opportunity by putting in place enabling policies.

[103] " MTN entered into an agreement to sell and lease back their towers to TowerCo Uganda Limited, a Joint Venture between MTN and American Tower Corporation (ATC). Eaton Towers Uganda Limited acquired took over the site portfolio of Orange Uganda Limited. Warid Telecom in March 2012 reached an agreement to transfer their passive infrastructure (Towers) to Eaton Towers U Ltd." UCC 2011-2012 Annual market review report

[104] "Renewable Energy Hybrid Systems for Telecom Towers.pdf," n.d.

What about demand for power and telecommunications services?

Although the majority of the Ugandan population lives in rural and remote areas of the country, the significant levels of poverty have continued to pose a challenge to the commercial economic viability of service provision to these populations. The access to power and telecommunication services has therefore been provided through shared social infrastructure, such as schools, multipurpose tele-centers and commercial battery charging centers or power hubs located in trading centers, where demand can be aggregated.

Demand is evolving

In many rural areas, the availability of mobile phone services has preceded the availability of electricity and as such, the need to power or charge mobile phones is spurring the demand for power. One of the key features of low cost mobile phone handsets is the lighting/torch functionality, which may be an indicator of likely demand for power to light households. Similarly, businesses trading solar lighting solutions have had to devise adapters to enable customers to charge mobile phones from these lanterns. Aside these functions, rural demand for electricity is centred on enabling micro enterprises and social welfare services such as health and education.[105]

A positive correlation has been found to exist between the ownership of mobile phones and access to electricity and in addition, the increased availability of electricity to charge phones has been linked to increased consumption of telecommunication services in rural areas. It thus appears that a synergetic relationship exists between the demand for power and telecom services.

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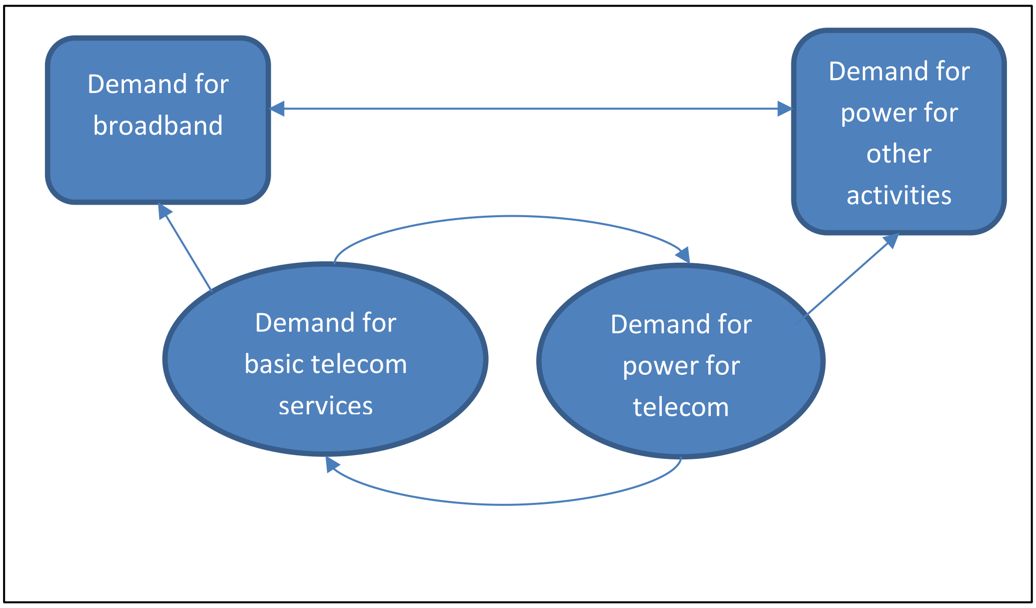
[105] "The Welfare Impact of Rural Electrification: A Reassessment of Costs and Benefits," 71, accessed July 14, 2013, http://siteresources.worldbank.org/EXTRURELECT/Resources/full_doc.pdf.

Figure 9: The feedback loops between demand for power and telecommunication services



Source: Author

The ability and willingness to pay

The willingness of rural populations to pay for services that add value to their lives such as telecommunications and electricity has been found to be high.[106] It is estimated that 24% of Ugandans are poor and live below the international poverty line. For those who are employed, with a median monthly wage of $30 and an estimated 10% expenditure on transport and communication, it appears that the ability to pay for power and telecommunication services is still low, especially amongst the rural population.

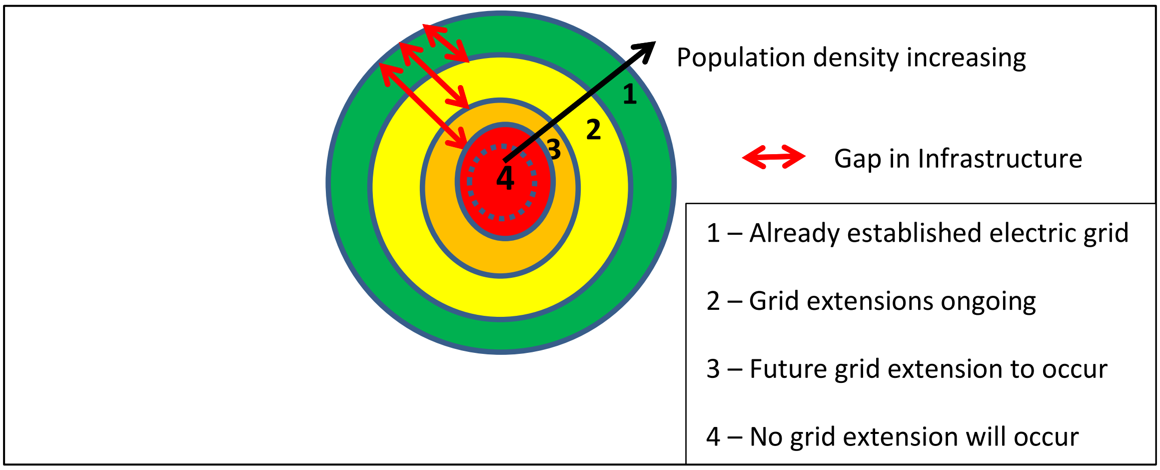
Therefore, despite the growing demand for power enabled by increased access to communication services, the low ability to pay, means that shared access to services for the communities will continue to be the more viable way of initially providing services.

[106] Ibid., 15.

Conclusion

The presence of scope economies for joint deployment based on the electric grid the absence of scope economies for joint deployment based on wireless base stations imply that economic incentive for joint deployment is likely to be greater in areas where grid extensions are on-going or will occur in the future, i.e. in the more densely populated areas. These densely populated areas dominantly lie in categories 1, 2 and 3. This is unfortunately inversely related to the gaps in infrastructure as the smaller gaps correspond to higher economic incentive.

Figure 10: Relating economies of scope to the gaps in infrastructure



Source: Author

However, examination of the benefits that accrue for the various stakeholders from joint deployment shows that there is still incentive for joint deployment in Uganda for both government and private stakeholders involved in the provision of power and telecommunication services. These benefits are currently not aligned in a way that promotes joint deployment, especially for areas in category 3 and 4, where the potential for joint deployment is most potent, due to the existing large gaps in infrastructure. Policies to facilitate the alignment of these benefits for the different stakeholders, in light of the inverse relationship of the need for deployment and economic incentive are thus required, in order for joint deployment to occur on a larger scale.

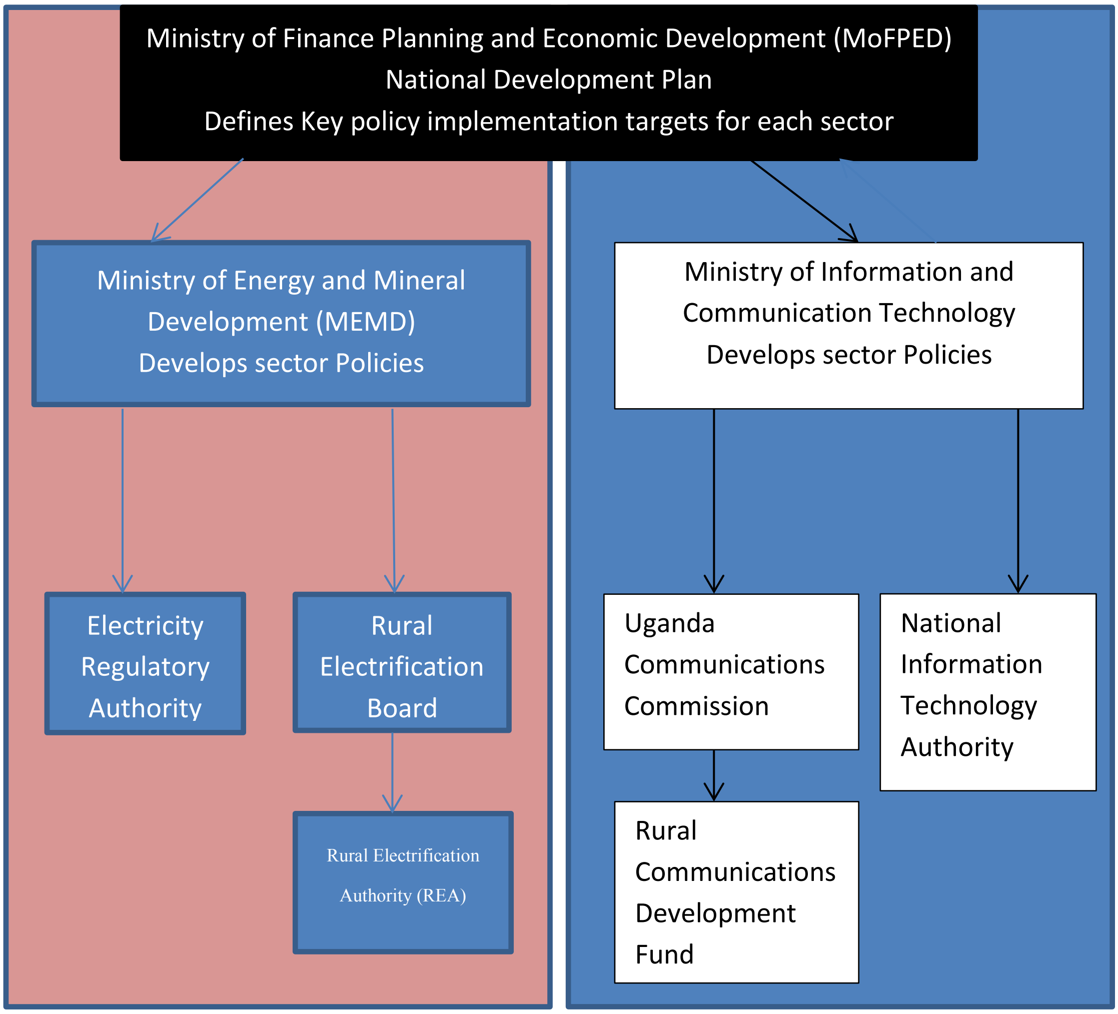
Chapter 6 Policy and regulatory issues related to joint deployment

This section reviews the existing policy and regulatory environment in Uganda, to identify whether any barriers to joint deployment exist and subsequently identifies measures that can be employed to foster joint deployment of power and telecommunications infrastructure in Uganda.

An assessment of the existing policy and regulatory environment

The power and telecommunications sectors are governed separately under the Electricity Act and the Communications Act respectively. The figure below shows the key policy and regulatory actors involved in the development and implementation of power and telecommunications policy in Uganda.

Figure 11: Government Policy stakeholders for Power and Telecommunications in Uganda



Source: Author

Alignment of policy stakeholder activities

At the highest level, the two sectors are aligned to achieve the objectives of the National Development Plan (NDP), through the implementation of activities, as guided by the respective sector policies[107]. The organisations established to implement the sector policies, as shown above, are autonomous except for REA which is semi-autonomous, and as such, these organisations function as independent agencies in the implementation of their given mandates, towards the achievement of a common goal of the NDP - sustainable development.

Potential hindrances to joint deployment

Based on the status of existing infrastructure for power and telecommunications in Uganda, it is apparent that joint deployment is taking place to a very limited extent. The only instance of joint deployment so far has occurred on the existing high voltage transmission grid, where UETCL is utilising the excess capacity within the optical fibre installed along the power lines, to provide transport capacity to telecommunication service providers[108]. No instances of joint deployment based on wireless base stations have so far been documented.

Given this low level of joint deployment so far, and the fact that there is still a lot of potential for the two forms of joint deployment to occur in Uganda, it is appropriate to identify how the existing policy and regulatory environment could be hindering joint deployment, as well as the potential remedies to those hindrances.

Lack of outcome based targets/objectives

The activities implemented by the various organisations within the two sectors are developed to meet sector specific targets, without due consideration to leverage the complimentary nature of the initiatives or infrastructure being implemented by the other sector.

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[107] "National Development Plan -Uganda.pdf," 2.
[108] "Uetclbusinessplan.pdf," 35.

Two examples of on-going infrastructure initiatives currently being implemented in Uganda demonstrate this. (1) The Energy for Rural Transformation (ERT) initiative – This is an example of an initiative, which takes cognisance of the interdependence between power, telecommunications and other social infrastructure. The key objective of the project is to increase access to energy and ICTs in rural Uganda through greater investments in infrastructure within the sectors[109]. Although there is a certain level of coordination in terms of where infrastructure is deployed, i.e. schools, health centers, local government offices and other social infrastructure, the deployments of power and telecom infrastructure are carried out independently, as separate components, without exploring the potential of sharing infrastructure to provide both power and telecommunication services. (2) The National Backbone Infrastructure project – This initiative will establish a national optical fibre backbone that traverses major towns in the country and connects government institutions. The backbone is being buried underground as a standalone infrastructure despite the fact that, parts of it could have been jointly deployed with electrical grid infrastructure, in areas where high voltage transmission grid extensions are on-going[110].

The sector specific focussed implementation of policy objectives thus limits the use of joint deployment which would result in better outcomes for the end users, and more efficient resource utilisation perhaps at a cost of lower sector infrastructure penetration (or performance) figures. The focus on sector specific targets is further reinforced by the institutional arrangements as discussed below.

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[109] "Uganda: Energy for Rural Transformation APL-2," *The World Bank*, accessed February 13, 2013, http://www.worldbank.org/projects/P112334?lang=en.

[110] Phase 4 of the NBI will be deployed to span the north east region of the country which also currently has no power grid infrastructure. There is still an opportunity as such to jointly deploy this infrastructure.

Weak institutional synergy

The institutions that develop and implement government policy within the two sectors, as shown above, are designed to operate independently focusing on specific aspects within the given sector. Frameworks for collaboration and resource sharing within and across sectors are adhoc in most cases and poorly established. The different institutions typically have slow bureaucratic processes, and tend to prefer maintenance of the status quo when implementing activities. These weak linkages amongst the institutions present a barrier to joint deployment.

Opportunities to foster joint deployment

The entry of UETCL into the telecommunications market was initiated by a request of the telecom companies to UETCL to provide transport capacity.[111] The successful entry and operation of UETCL demonstrates that the existing policies and regulations can facilitate joint deployment. Additional policies and regulatory measures that have been used in other places in the world and could be used in Uganda to foster this cross sector collaboration are discussed below.

National Broadband Plans/strategies

Uganda is in the process of developing broadband infrastructure as a tool for accelerating social-economic development. The ITU notes that "The challenge is to leverage broadband in a way that helps accelerate development where it is most needed", and as such, it recommends that "National Broadband strategies should be used as a vehicle for cross sector collaboration and cross ministry coordination supporting a common vision and enabling broadband applications and services to develop most effectively" [112]. Joint deployment of power and telecommunications

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[111] "Uganda Electricity Transmission Company to Lease Part of Its Fibre Optic Network Capacity | Balancingact-africa.com," accessed March 25, 2013, http://www.balancingact-africa.com/news/en/issue-no-404/internet/uganda-electricity-t/en.
[112] "Bb-annualreport2012.pdf," n.d., 19,38.

infrastructure provides this opportunity to develop broadband services in an effective way in rural areas.

A broadband infrastructure strategy was recommended to guide the development of broadband infrastructure in Uganda. The strategy assessed the demand and supply needs required for broadband to facilitate development in Uganda. Demand for broadband within the strategy is well integrated into other social infrastructure developments and services such as schools and hospitals with clear objectives laid out for enabling their connectivity[113].

Although the strategy mentions the possibility of leveraging electrical infrastructure to rollout fibre optic backbones, and also highlights the challenge of limited electricity access by rural populations as a hindrance to the use of broadband, it is silent on identifying specific areas and ways in which cross sector collaboration can be implemented to address these challenges.[114]

Brazil provides a good example of using a national broadband plan to enable cross sector collaboration. Having identified the constraint of limited national backbone capacity, the national broadband plan was used to facilitate collaboration between electricity, rail and oil pipeline infrastructure owners such that existing optical fibre within these facilities could be leveraged, to provide wholesale capacity to other operators[115]. This has fostered broadband availability in remote areas, making Brazil one of the fastest growing Internet markets today.

In Uganda's case, the broadband infrastructure strategy could map out areas where the national optical fibre backbone could ride on existing planned electricity grid extensions as well as infrastructure of other potential alternative providers such as railroads and oil pipelines that are currently under development.

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113 "UBIST Final Draft.pdf," n.d., 28–33.
114 Ibid., 35.
115 Mike Jensen, *Broadband in Brazil: A Multi Pronged Public Sector Approach to Digital Inclusion*, 2011.

'Dig once' Policies

Dig once policies apply to infrastructure that is buried underground. These policies are meant to ease the barriers to installation of new infrastructure, such as acquiring rights of way, high costs for civil works installation, as well as the destruction and disruption caused to existing infrastructure, specifically roads. A dig once policy basically mandates that all parties intending to bury infrastructure along a given route must do it at the same time or install facilities such as conduits that will prevent those who install infrastructure later on from breaking earth again.[116]

In the United States, a dig once executive order was issued to facilitate the development of optical fibre access and last mile infrastructure, in order to facilitate achievement of the National Broadband Plan goals. The policy has also been considered in Latin America so as to fast track the development of broadband infrastructure[117].

Although currently in Uganda the electricity distribution lines are installed overhead, the policy can still be applied to foster joint deployment in the development of other infrastructure such as roads, rail and pipelines.

Facilitate access to mutually beneficial infrastructure

Joint deployment is based on the premise that parts of the infrastructure used to provide one service can be leveraged to provide a different service. Utility Pole access rules have been used in the United States and Europe to facilitate deployment of infrastructure for telecommunication services.[118] Joint deployment leveraging wireless base stations may require that base station infrastructure

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[116] *The State of Broadband 2012: Achieving Digital Inclusion for All* (International Telecommunications Union, 2012), 69.
[117] "Broadband in Latin America - IDB Report," 21, accessed March 6, 2013, http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=36882814.
[118] Beard, Ford, and Spiwak, "The Pricing of Pole Attachments."

owners share certain infrastructure to facilitate development of power infrastructure, as described in chapter 4 on joint deployment.

Regulators should be developed to facilitate this cross sector collaboration, so as to leverage infrastructure that is mutually beneficial to the development of power and telecommunications infrastructure.

Conclusion

The existing policy and regulatory environment in Uganda is biased by design towards independent deployment of infrastructure. In order to facilitate joint deployment, there is need to establish stronger frameworks for cross sector collaboration. Since joint deployment may create shared responsibilities or ownership of assets, these collaborative frameworks should not create new jurisdictions, but should seek to complement existing frameworks in order to foster joint deployment.

The opportunities for improvement of the policy frameworks discussed within this section provide initial steps for such cross sector collaboration to foster joint deployment, however, there is need for deeper examination of the policies related to infrastructure development for power and telecommunications in rural areas, in order to realise the opportunities identified for joint deployment in Uganda

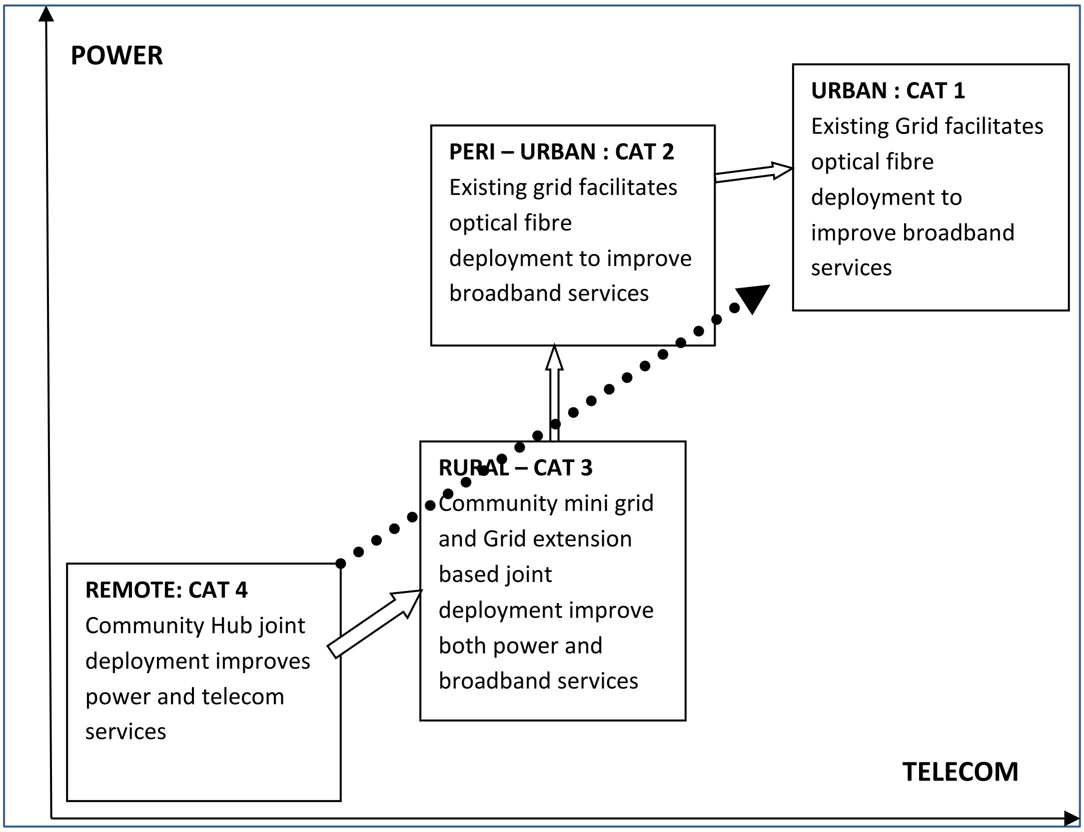
Chapter 7 Summary, Conclusions and Recommendations

Summary

This research identifies 2 options for the joint deployment of power and telecommunications infrastructure in Uganda; (1) Joint deployment based on the electric grid (2) Joint deployment based on wireless base stations with either a community power hub or a community micro grid. These options can be implemented for the deployment of new infrastructure or through incremental deployments based on current infrastructure deployments.

Based on a categorisation of areas depending on social economic activities and the existing power and telecommunication services, the current options for joint deployment in each of the areas are shown in the figure below. The figure also shows that remote areas may be able to transition to better levels of power and telecommunication services through joint deployment of infrastructure.

Figure 12: The roadmap for joint deployment



Source: Author

For grid based and the community hub model of joint deployment, scope economies exist and as such, these will be the initial forms of joint deployment that occur. However, for joint deployments based on the community mini grid model, the alignment of incentives for the government and private stakeholders will play a key role in enabling it to happen since no economies of scope accrue for the telecom providers.

Recommendations

Infrastructure deployments are highly influenced by the policy and regulatory environments for both the power and telecommunications sector. In light of the potential for joint deployment to be implemented in Uganda, the following recommendations are thus made, in order to foster joint deployment in Uganda:

STAKE HOLDER		Recommendation
Government	UCC & ERA	Encourage infrastructure sharing for wireless base stations in remote areas which will foster community hub joint deployments
		Encourage power infrastructure owners to share infrastructure with communications service providers by creating clear regulations for pole access and infrastructure sharing with communications sector users
		Encourage use of renewables for rural telecom infrastructure

		deployments
		Review policies related to power and telecommunications infrastructure development to enable alignment of economic incentives for the various stakeholders
	REA & RCDF	Establish collaborative working group to identify, plan and coordinate joint deployment initiatives within existing infrastructure development plans. This could include the consideration of a joint subsidy for joint deployments in certain areas

Source: Author

Conclusion

Although there is greater economic incentive for joint deployment based on the electric grid due to accrual of scope economies, the slow rate of grid development delays the realisation of the benefits of joint deployment limits the applicability of this option, given the faster rate of development of telecommunications. Thus, despite the nascent stage of maturity of joint deployment based on wireless base stations, the fact that base station infrastructure is faster to develop and is already more widespread than the electric grid in Uganda, presents a greater opportunity for the quicker realisation of development benefits through joint deployment.

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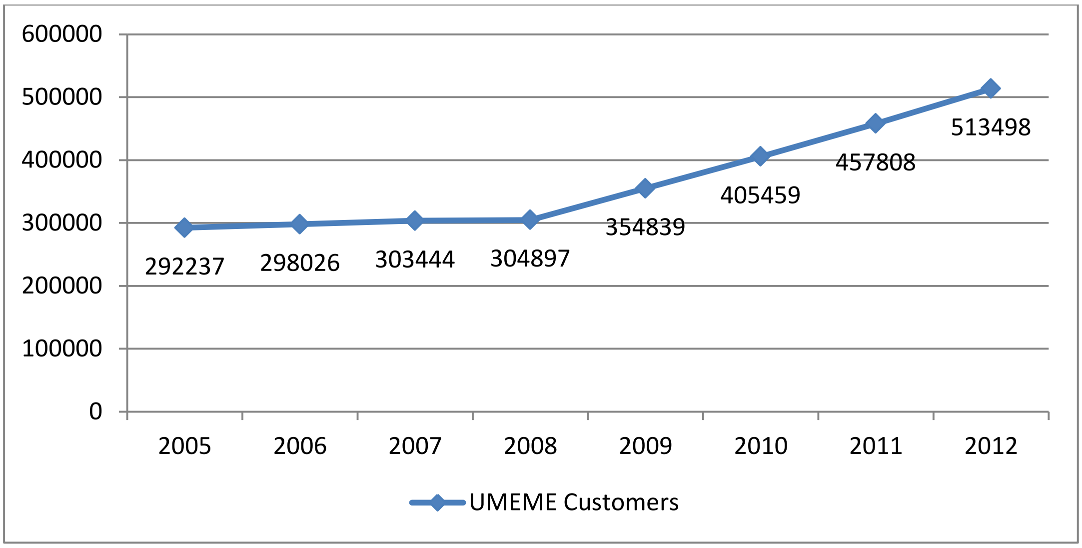
Appendix 1

UMEME Customer growth 2005 -2012



Source: UMEME Limited

Appendix 2

Isolated Mini grids in Uganda

Plant Name	Type of generation Source	Installed generation Capacity	Area of service/Use/No of customers	Owner & operator
Kisiizi	Micro Hydro	350KW	Kisiizi Hospital and surrounding area (an estimated 300 customers)	Kisiizi Power Ltd
Kuluva	Micro Hydro	120KW	Kuluva hospital	Kuluva hospital
Kagando	Micro Hydro	60KW	Kagando hospital	Kagando hospital
Arua	Thermal (HFO)	1.5MW	Arua town	WENRECO
Moroto	Thermal (diesel)	750KVA	Moroto town	UEDCL
Adjumani	Thermal (diesel)	750KVA	Adjumani Town	UEDCL
Moyo	Thermal (diesel)	750KVA	Moyo Town	UEDCL
Bugala (Kalangala)	Thermal (diesel)	250KVA	Bugala Island	UEDCL

Source: Ministry of Energy and Mineral Development

Appendix 3

Core Network

The key function of the core network is to implement switching among users of the telecommunications network, since the intelligence used to initiate and route traffic is stored in this part of the network. In addition, the core network provides the interfaces necessary for interconnection with other networks. Other network functions carried out in the core network include billing, authentication and subscriber profile management.[119]

As telecommunications networks have evolved to provide data and Internet connectivity in addition to voice telephony, the core network infrastructure is expanding to include packet switching nodes in addition to the traditional circuit switching nodes. Although the physical space required for the core network infrastructure is decreasing over time, the power needed to operate core network infrastructure is increasing. This is due to the fact that the core network functionality and capacity of core network nodes is growing to accommodate the complex functionality and diverse services offered by telecommunications networks today.[120]

In Uganda, the power for core network nodes is supplied by mains power and battery backup systems that are installed alongside the equipment according to its required consumption.

119 Mishra, *Fundamentals of Cellular Network Planning and Optimisation*, 15.
120 W. Vereecken et al., "Power Consumption in Telecommunications Networks: Overview and Reduction Strategies," *IEEE Communications Magazine* 49, no. 6 (2011): 5, doi:10.1109/MCOM.2011.5783986.

Last mile

The term “last mile” refers to the connection between the end user device, such as a phone, and the provider’s network that enables the customer to send and receive information. Historically, the last mile has always been a low capacity link since its use was limited to only a single user. However, this is changing due to the increasing need for larger bandwidth by end users for the use of broadband services and applications.

Similar to developments in the backbone and access network, optical fibre is currently the preferred wire line technology in the last mile for broadband connectivity. Broadband delivery using networks based on copper and coaxial cable are often hybrid networks integrating optical fibre to enhance the network transmission capabilities.

For wireless technology in the last mile, however, the connection to the end user device from the nearest network access point is made over the air interface, using radio waves, at specifically designated frequencies. The characteristics of this connection are governed by the access network technology in use as well as the end user device capabilities.

Appendix 4

A snapshot of broadband service options in Uganda

Technology	**Coverage**	**No. of providers**	**Target Users**	**Achievable Theoretical data rates**
GPRS & EDGE	Kampala, major towns and rural areas with GSM coverage	5	Individuals and SOHO	175Kbps
3G/3G+ (HSPDA)	Kampala and major towns	5	Individuals and SOHO	3.6Mbps to 21.6Mbps
WiMAX	Mainly in Kampala and some major towns	3	Corporate and SOHO	30Mbps-40Mbps
CDMA EV-DO	Kampala and some major towns	1	Individuals and SOHO	3.5Mbps
VSAT and Microwave links	Mostly Kampala and in between major towns	ALL	Large corporates Service providers	Capacity available as required
ADSL	Mainly Kampala and other major towns that had copper landline infrastructure	only 2 providers	Corporate and SOHO	Up to 9Mbps dependent on distance from switch node
Metro Ethernet	Kampala	1	Large Corporate	
Optical Fibre	Mostly Kampala and in between major towns	4	Service providers	Capacity available as required

Source: Adapted from Nahid

Appendix 5

Telecom Infrastructure facilitated by RCDF[121]

Infrastructure Type	**No. of facilities setup**
GSM Voice sites	90
Internet Points of Presence	76
Payphones	4099
Internet Cafes	106
Multipurpose community tele-centers	13
School ICT Laboratories	708
Health ICT facilities	174

Source: RCDF

[121] "About RCDF."