

Research Application Summary

Telecom network energy management for sustainability in sub-Saharan Africa: Towards a solution through a systems approach

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Abstract

A dependable, economically viable, environmentally friendly and sustainable energy system is a foundation of any modern society. The Sub-Saharan Africa (SSA) telecommunications industry has seen, in the last years, a significant surge in fossil powered network infrastructures including in hardly reachable off-grid areas and the relevant hike of energy consumptions because of increased demand for capacity and coverage in order to ensure quality of service anywhere and anytime. The considerable problems resulting from high energy consumptions and from relevant environmental emergency due to emissions of greenhouse gases have pushed companies to devise novel, clear, defined and holistic approaches so as to optimize actions fit for fulfilling the urging and growing energy management demands. Improving energy management for telecom networks is not only a crucial contribution towards the fight against global warming, but with the swiftly hiking energy prices, it is also becoming a financial opportunity. Companies believe that custom power supply specifications and strategies especially for hardly reachable off-grid areas such as, efficiency, sustainability, reliability and cost-effectiveness can be best solved by utilizing advancements in technical solutions, for example, renewable energy. This renders the current trends and practices of managing energy in telecom networks across SSA more of a reductionist approach. Amidst the substantial renewable energy resources, the SSA telecom industry hasn't adopted the idea of greening to the expected potential to provide sustainable power to industries and communities across the region. This paper seeks to analyze the key barriers that have hampered greening of telecom networks across SSA and then propose a conceptual framework based on systems approach for guiding policy makers, stakeholder groups and governments as far as energy planning and management strategies are concerned. It incorporates technical, financial, operational and ecosystem factors.

Key words: Barriers, cost-effectiveness, reliability, sustainable power, sub-Saharan Africa, Telecom network greening

Résumé

Un système énergétique fiable, économiquement viable, respectueux de l'environnement et durable est le fondement de toute société moderne. L'industrie des télécommunications de l'Afrique sub-saharienne (ASS) a connu, ces dernières années, une augmentation significative des infrastructures de réseau à énergie fossile, y compris dans les zones hors réseau difficilement accessibles, et une augmentation correspondante de la consommation d'énergie en raison de la demande accrue de capacité et de couverture afin d'assurer la qualité du service partout et à tout

moment. Les problèmes considérables résultant des fortes consommations d'énergie et de l'urgence environnementale liée aux émissions de gaz à effet de serre ont poussé les entreprises à concevoir des approches nouvelles, claires, définies et holistiques afin d'optimiser les actions permettant de répondre aux demandes pressantes et croissantes de gestion de l'énergie. L'amélioration de la gestion de l'énergie pour les réseaux de télécommunications n'est pas seulement une contribution cruciale à la lutte contre le réchauffement climatique, mais avec la hausse rapide des prix de l'énergie, elle est également devenue une opportunité financière. Les entreprises estiment que les spécifications et les stratégies d'alimentation en énergie personnalisées, telles que l'efficacité, la durabilité, la fiabilité et la rentabilité, en particulier pour les zones hors réseau difficilement accessibles, peuvent être mieux résolues en utilisant les progrès des solutions techniques, par exemple, les énergies renouvelables. Les tendances et les pratiques actuelles de gestion de l'énergie dans les réseaux de télécommunications en Afrique subsaharienne relèvent donc davantage d'une approche réductionniste. Malgré l'existence d'importantes ressources d'énergie renouvelable, le secteur des télécommunications de l'Afrique subsaharienne n'a pas adopté l'idée de l'écologisation au potentiel attendu pour fournir une énergie durable aux industries et aux communautés de la région. Cet article cherche à analyser les principaux obstacles qui ont entravé l'écologisation des réseaux de télécommunications en Afrique subsaharienne et propose ensuite un cadre conceptuel basé sur une approche systémique pour guider les décideurs, les groupes de parties prenantes et les gouvernements en matière de planification et de stratégies de gestion de l'énergie. Il intègre des facteurs techniques, financiers, opérationnels et écosystémiques.

Mots clés : Obstacles, rentabilité, fiabilité, énergie durable, Afrique subsaharienne, écologisation des réseaux de télécommunication

Introduction

A dependable, economically viable, environmentally friendly and sustainable energy system is a foundation of any modern society (World Economic Forum, 2017). According to Beuth Verlag (2007), "Energy management includes planning and operation of energy production and energy consumption units. Objectives are resource conservation, climate protection and cost savings, while the users have permanent access to the energy they need. It is connected closely to environmental management, production management, logistics and other established business functions".

The significant growth in network connectivity has caused the mobile industry to increase its impact across all the UN's SDGs (Sustainable Development Goals), and this has also stimulated the adoption of mobile-based tools and solutions (e.g. in education, healthcare and agriculture) that target livelihood improvements especially across SSA countries (GSM Association, 2019). Owing to this unexpected growth in network connectivity, Mobile Network Operators (MNOs) are expanding their infrastructures rapidly to match with the trending user demand. The growth in mobile network infrastructures has extensively outweighed the grid electricity infrastructure expansion especially in sub-Saharan Africa (SSA) leading to overreliance on fossil fuel power systems for powering a considerable number of off-grid sites amidst their high operational, logistical, economical and environmental challenges (Hasan *et al.*, 2011; Jahid *et al.*, 2018). The high energy consumption has received a significant attention in relation to the future energy availability with its associated costs while considering the scarce fuel energy sources available (Rahman, 2018). The worldwide climatic change caused by high CO₂ emissions and the rest of greenhouse gases in the atmosphere is regarded as the most crucial global emergency that

necessitates effective and immediate policies (IPCC, 2007). The CO₂ emissions are mainly caused by fossil fuel energy sources. Hence, the future usage of them must be decreased. This can be through the improvement of energy management approaches like the usage of large scale renewable energy sources (Lubritto, 2010, 2014).

Kanzumba (2013) and Alsharif *et al.* (2015) report that in 2013, the global mobile network subscribers' number had reached 6.8 billion and 1 billion were in rural areas being served by off-grid sites. Also, a report by GSMA (2014) shows that majority of uncovered population for mobile connectivity (around 300 million people) live in rural and remote areas of Africa without access to grid electricity and road infrastructure, thus resulting to higher operational costs and poor Return On Investment (ROI) on the side of service providers. In an attempt to access these new markets and provide services to these customers located in hard-to-reach rural areas, the number of Base Stations (BSs) has been extended to satisfy customer needs and increase areas of coverage. Traditionally, a Diesel Generator (DG) is deployed for supplying electrical power to these sites which are off-grid (Alsharif *et al.*, 2014). The idea of using DGs to power BSs by operators in order to expand and deliver network services to potential new subscribers has become inappropriate due to problems associated with sustainability, efficiency, reliability, and cost-effectiveness (Alsharif *et al.*, 2015).

A critical analysis of the current practice by Andrew and Petkov (2003) and Nikola Asurdzic (2014) indicate that MNOs only focus on technology adjustments in finding energy management solutions without any imperative to think in terms of the technology being an intervention into a society. As such MNOs believe that custom power supply needs and specifications for telecom networks for example efficiency, sustainability, reliability and cost-effectiveness can be best solved by utilizing the technological advancements in renewable energy (Alsharif *et al.*, 2015). The deployment of these network technologies in these remote off-grid locations need to consider holistic benefits of all related stakeholder groups. The operation of these energy systems mainly reliant on Renewable Energy Technologies is technologically feasible, but can be institutionally complex (Papaeftymiou and Dragoon, 2016). The complexity of this envisioned transformation strongly demands the development of a conceptual framework that can enable a systemic interaction to cause changes in the various economic, technological and other institutional aspects which this paper sets out to answer.

In Bale *et al.* (2015), it is said that Energy systems can be perceived as complex adaptive systems because their components are interconnected, interrelated and heterogeneous (agents and objects). Due to lack of autonomous control over the whole systems, a self-organizing emergent behavior appears which cannot be foreseen by the comprehension of each of its constituent elements independently.

Using systems knowledge and a proper analysis of the factors hampering SSA telecom network greening, one can propose that the current practices are not comprehensive enough for a healthy telecom energy system to develop because they apply a reductionist approach. The next section discusses the research approach used to generate opinions.

Research Approach. For this paper, literature in relation to powering of telecom networks, energy management strategies and systems approaches was reviewed. The key barriers that have hampered greening of Telecoms in SSA context were also analyzed. Imperfections and gaps in the current telecom network energy management approaches call for the proposition of a holistic approach for managing energy in telecom networks which may serve as a guide to policy makers,

stakeholder groups and governments as far as energy planning and management strategies are concerned. This holistic or systemic approach strongly demands the development of a strategy or conceptual framework that can enable a systemic interaction to cause changes in the various economic, technological, ecological, social and other institutional aspects which this paper sets out to propose. The next section analyses the literature related to our subject.

Literature Review and Analysis

Reflecting on the last decade of research, scientists have made a significant and remarkable progress concerning energy management in Telecommunications networks. A considerable number of research papers tackle areas of improving energy management by telecom companies but the subject area is explicitly dominated by a technical perspective (Marsan *et al.*, 2013; Alsharif *et al.*, 2015; Andrae and Edler, 2015; Chamola and Sikdar, 2016; Ahmed *et al.*, 2017; Jahid and Hossain, 2017; Sheng *et al.*, 2017; Jahid *et al.*, 2018; Jahid and Hossain, 2018; Rahman *et al.*, 2018; Dawadi *et al.*, 2020). It is more of a reductionist approach because it is inclined to only technical solutions and neglects other factors that may be crucial for the holistic planning and management of energy in telecom networks across SSA. This holistic approach would ensure the counteraction of the negative emergent properties of a complex energy system which ensures benefits of all the stakeholder groups.

Dawadi *et al.* (2020), based on techno-economic and managerial perspectives, urges governments to focus on green networking due to the severity of global warming impact and climate change especially in developing countries. Alsharif *et al.* (2015) and Rahman (2018) examined the practicability of a hybrid solar Photovoltaic/Diesel Generator(PV/DG) system for powering remote off-grid BSs in Bangladesh focusing on reducing the over dependency on fuel energy sources and also to minimize the carbon emissions or rate of pollution. Sheng *et al.* (2017) discovered that grid-renewable energy combination can save energy using energy sharing and load shifting approach. Jahid *et al.* (2018) proposed an energy efficient hybrid framework for PV panel with adequate storage capabilities which acts as the main power source for powering BSs with the grid energy assumed as a standby source of power. Chamola and Sikdar (2016) asserts that renewable energy powered BSs have become a promising solution to off-grid power challenges in developing countries. Marsan *et al.* (2013) adds that solar powered BSs not only reduce the carbon footprint of cellular networks but they can also be implemented with lower capital expense compared to grid-based or conventional-based energy source. Elkazzi and Khalil (2018) suggested the adoption of a cooperative management between two operators offering network resources in the same region focusing mainly on GHG emission reduction and minimization of operational expenditure (OPEX) for cellular networks. Ahmed *et al.* (2017) emphasized the potential of renewable energy power sources in achieving greener ICT and adds that support from government bodies, organizations and industry is required for R&D actions cutting across disciplines and themes related to energy efficiency.

The operation of energy systems mainly reliant on RETs and other sustainable energy management approaches is technologically feasible, but can be institutionally complex. Recent studies have identified a big gap in industries pertaining energy efficiency potential which isn't yet exploited (Papaefthymiou and Dragoon, 2016). With a thematic research focus, it is revealed and evident that the energy management measures are explicitly dominated by technical perspectives. Our analysis show that the current studies do not express best-practice examples of attaining improved energy management through embracing new routines and deploying adapted and holistic processes in energy management. As governments try to enforce energy efficiency measures amidst increasing

energy prices, MNOs will definitely be compelled to put much emphasis to energy management at strategic level (Rudberg *et al.*, 2013). This will require particular mechanisms that deal with the process of strategy implementation by utilizing resources as well as influencing individuals and unified action towards energy-related objectives. The next section gives a discourse on the current trend of energy management in telecom networks across SSA.

Current trends in Energy Management. Sub-Saharan Africa has a significant resource potential but the power sector still faces issues of insufficient generation capacities, lack of adequate transmission and distribution infrastructure, poor power supply quality and over reliance on unclean fuel based power sources (IFC and GSMA, 2014). Renewable energy technologies have been proposed as the main viable solution for optimizing the energy mix and increase access to electricity in SSA (IFC and GSMA, 2014). In SSA, electricity blackouts occur on a daily basis hence people and enterprises consequently rely on expensive diesel generated power to meet their electricity needs especially in the Telecom power sector. This has cost some SSA economies between 1% and 5% of GDP annually, in addition to being environmentally un-clean (IFC and GSMA, 2014). In order to ensure full availability and quality of power during outages, mobile operators have been forced to deploy backup power sources such as batteries and diesel generators, even at grid-connected sites (GSMA, 2014). Any efforts by the MNOs and Tower Companies intended to curb down over dependence on diesel would interfere with the interests of diesel value chain which has tightened its grip as telecom infrastructure enlarged (GSMA, 2015). This causes challenges for SSA countries in making energy choices that can reap the benefits of socio-economic and environmental sustainability.

The evident gap here is that Telecom networks typically only focus on having energy issues solved for example by deployment of renewable energy technologies without proper analysis of emergent properties. If the telecom network energy management process is to ensure universal stakeholder benefits, a holistic telecom network energy management process must be duly embraced. The next section presents the current state of greening in SSA telecoms.

Current state of Greening in Telecom Networks. Green deployments in the wider Africa have not attained the expected potential scale possible for green power adoption in the telecom industry. Figure 1 shows the status of green deployments of different technologies for African telecom networks as of 2014. The geographical scope of this data is limited to Africa and mainly SSA.

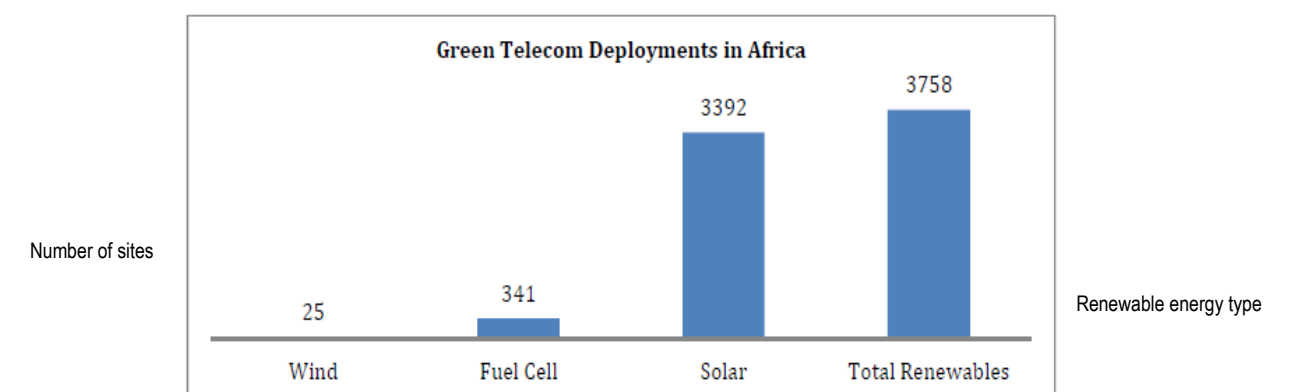


Figure 1. Green power deployments in Africa
(GPM Deployment Tracker, 2014)

Figure 1 indicates that as of 2014, Africa had a total of less than 4000 sites deployed with green power technologies and almost all of them are off-grid sites. This was less than 3% of the total off-grid sites in SSA and against global average of 13%. Solar is the most widely used with over 3300 deployments, accounting for nearly 90% of total green deployments. Albeit the green energy price has never been low, the percentage of SSA's cell sites utilizing green energy is still in single digits (TowerXchange, 2020). TowerXchange, (2020) also asserts that MNOs in SSA can be among the largest power generators across the continent – this is a position the MNOs are not interested to hold.

The following section discusses the analysis of the barriers impeding the success of telecom networks' greening across SSA.

Barriers to Telecom Network Greening. SSA has substantial renewable energy resources but its telecom industry has not adopted the idea of greening to the expected potential to provide sustainable power to industry and communities across the country (GSMA, 2014; TowerXchange, 2020). According to GSMA (2014, 2015), IFC and GSMA (2014), GSMA GPM Market Research and Analysis (2015) and TowerXchange, 2020, the main factors and challenges hampering the green power adoption in SSA Telecoms are:

Financial: Funding choices in addition to internal budgets, Limited knowledge and support from commercial banks to finance green deployments, Proven business models for off-loading the funding requirement,

Operational: Reliability of technology and vendors, Theft, vandalism of equipment, lack of committed support from partners at ground level,

Technology: (Availability and cost of technology, Limited skills on technology selection and right solution dimensioning, Technical support post deployment,

Eco-system: Availability of reliable operational partners and technology vendors, Local knowledge and technical support, and Regulatory support and policy guidelines to drive the green adoption. The changing industry structure also is to blame for impacting the pace for green adoption.

The analysis of these factors makes it clear that their synergistic interactions conspire to hamper green power adoption in SSA's Telecoms. This makes it a complex system and hence this complexity can only be overcome by a systematic and systemic intervention/approach which this paper aspires to propose. The next section gives a discourse on energy management as a pre-requisite for sustainability.

Energy Management as Justification for Sustainability. Energy is a necessity for the health, comfort and economic activities of people (ITU, 2017). Inexpensive and reliable energy is necessary for economic growth and reduction of poverty but to avoid negative climate changes with their associated dangers, there is a need to decouple economic growth from energy consumption. The significance of energy as a tool for global sustainable development is included among the 17 SDGs that were approved by the UN. Indeed SDG 7 particularly talks about the issue of a universal inexpensive and reliable energy access.

According to Ruteh (2011), energy efficiency is the most substantial, quickest and cheapest means of preventing environmental destruction. Sustainable development is a changing process,

including technology, orientating technology and institutions to be compatible with the present and future. Energy is very crucial in a bid to achieve sustainable development. To attain sustainable development and improve efficiency services, best and efficient means of utilizing energy have to be assessed and practiced. Energy management as a concept encompasses energy efficiency, energy saving, energy costs, energy tariffs and determination of clear energy type. The issue of energy management has been underpinned by the close relationship between energy and the environment. Fundamentally, energy management aims at producing goods and offering services with a low cost and environmentally friendly manner (Ruteh, 2011).

Energy management improvement of telecom networks is not just an essential contribution to combat global warming but with the swift increase in the energy prices, it is becoming a financial or economic opportunity for sustainable development (Lubritto, 2014). Hence clear, defined and holistic methods must be devised for optimizing actions of energy management. The next section discusses the proposed conceptual framework based on the analyzed literature and greening barriers.

Results and Discussions: Proposed Systems Conceptual Framework

Some frameworks have been suggested in literature mainly to guide in curbing the persistent energy predicament in the African continent by taking advantage of the naturally endowed renewable energy sources (Aliyu *et al.*, 2018). This analysis reveals that most energy studies divert from social sciences and focus on engineering and economic disciplines ignoring the need for social science aspects to be captured during technology design and pricing processes.

Good insights were picked from Ahlborg and Sjöstedt (2015) who explained the processes used by Italian NGO to succeed in implementing a small-scale off-grid hydropower project in Tanzania. The strategies employed included - active enhancement of productive electricity use, community services and benefits that gave rise to customer base, community engagement and ownership. The study theorizes electrification as a dynamic process of forming a novel socio-technical system combining people, technology, institutions and resources into a particular relationship. This assisted in analyzing how various factors manifest, interact and play out in practice. Brent and Kruger (2009) also proposes a holistic and integrated framework for implementing RET delivery. It is centered on social and institutional, technological, ecological and economic dimensions, and also asserts that rural energy doesn't just focus on technology choice, but also about holistic development.

According to Foxon (2011), a transformation to a sustainable low carbon economy necessitates progressive adjustments in systems that provide energy and other services for individuals, communities and businesses. This includes adjustments to energy use practices, innovations and deployment of various low carbon technologies, plus a wider adjustment within the mix of industries in national and global economies. The adjustments need to have a positive impact on economic prosperity in a socially equitable way as well as ensuring that these socio-economic systems stay in ecological boundaries.

After carrying out general analytical consideration and assessment of the relevant literature while cognizant of the main factors and challenges hampering the green power adoption in SSA telecoms reported by (GSMA, 2014, 2015; IFC and GSMA, 2014; GSMA GPM Market Research and

The sub-factors that lie under technical factors in relation to better energy management of telecom networks across sub-Saharan Africa include; Availability and cost of technology, skills on technology selection and right solution dimensioning, Technical support post deployment among others (Painuly, 2001; Urmee *et al.*, 2009; Barry *et al.*, 2011; Foxon, 2011; GSMA, 2014, 2014, 2015; IFC and GSMA, 2014; GSMA GPM Market Research and Analysis, 2015; Naicker and Thopil, 2019). This section also encompasses developing shared meanings related to ways in which a technology can be utilized e.g. mainly for business, recreation or social purpose or all.

Financial factors: There is a causal relationship between financial factors and economic factors (Ihsan *et al.*, 2007). Financial factors are very crucial for driving an increased adoption of better energy management approaches and business strategies/models due to high CAPEX needs. Among the sub-factors involved here in relation to better energy management of telecom networks across sub-Saharan Africa include; funding choices in addition to internal budgets (scarcity of external funding),knowledge and support from commercial banks to finance green deployments, and proven business models/strategies for off-loading the funding requirement among others(Painuly, 2001; Urmee *et al.*, 2009; Barry *et al.*, 2011; Foxon, 2011; GSMA, 2014, 2014, 2015; GSMA GPM Market Research and Analysis, 2015; IFC and GSMA, 2014; Naicker and Thopil, 2019). Through business strategies, firms may arrange their enterprises so as to accomplish some socio-economic purposes (Foxon, 2011). Business models and strategies widely defined with regard to socio-economic purposes encompasses social activities/enterprises that are more devoted to delivering goods and services to citizens and local communities without necessarily yielding a profit or financial returns for example for telecom companies, it is believed that Mobile Enabled Consumer Services (MECS) like retail power and water have the capacity to improve the social well-being (GSMA, 2014).

Operational factors. Operational factors are related to the day-to-day running of a telecom organization. The sub-factors embedded in operational factors in relation to better energy management of telecom networks across sub-Saharan Africa include; Reliability of technology and vendors; society/community ownership/support necessary to improve site security, theft, vandalism of equipment by local communities affecting the reliability and predictability of network operations, committed support from partners at ground level (availability of reliable operational partners) among others (Painuly, 2001; Urmee *et al.*, 2009; Barry *et al.*, 2011; Foxon, 2011; GSMA, 2014, 2014, 2015; GSMA GPM Market Research and Analysis, 2015; IFC and GSMA, 2014; Naicker and Thopil, 2019).

Eco-system factors. These are factors that define the relationship of partners and vendors, local communities and the politics in a given area. The collaborative efforts within the telecom industry can impact the telecom network greening scalability. The sub-factors that lie under political factors in relation to better energy management of telecom networks across sub-Saharan Africa include; Local knowledge and technical support, availability of reliable operational partners and technology vendors, regulatory support and policy guidelines to drive the green adoption which includes unrealistic political commitment through plans and targets, among others (Painuly, 2001; Urmee *et al.*, 2009 Barry *et al.*, 2011; Foxon, 2011; GSMA, 2014, 2014, 2015; GSMA GPM Market Research and Analysis, 2015; IFC and GSMA, 2014; Naicker and Thopil, 2019). The possible areas where the proposed conceptual framework can be applied are discussed next.

Analysis, 2015; TowerXchange, 2020), and borrowing ideas from systems engineering and praxis, sustainability thinking (SEBoK, 2014), socio-technical systems/transition (Geels, 2004, 2010; Williams *et al.*, 2017), this research identifies the key systemic structural components of - technology (technical), financial, operational, and eco-system to formulate a systems approach conceptual framework (Figure 2) for guiding the management of energy in telecom networks across SSA.

Figure 2 can enable us to systemically analyze the relationships, influences of system components towards the sustainable energy management practices across SSA telecom networks. The value of this conceptual framework is that it focuses attention on the most relevant factors, while trying to avoid being a ‘theory of everything’. In order to contribute to sustainable development, the elements identified must successfully relate and interact to achieve a mutual objective.

For purposes of clarity, the different systems/factors in the context diagram and their related interfaces are expounded. The descriptions are not definitive but they provide a base required for inter-disciplinary work in relation to guidance on sustainable energy management across Sub-Saharan Africa.

Technology (Technical) factors involve influences that have an impact on how telecom networks operate and are related to the equipment used in the organizations’ environment. According to (Arthur, 2009; Foxon, 2011), technologies are “a collection of (natural) phenomena captured and put to use...to fulfill a human purpose”.

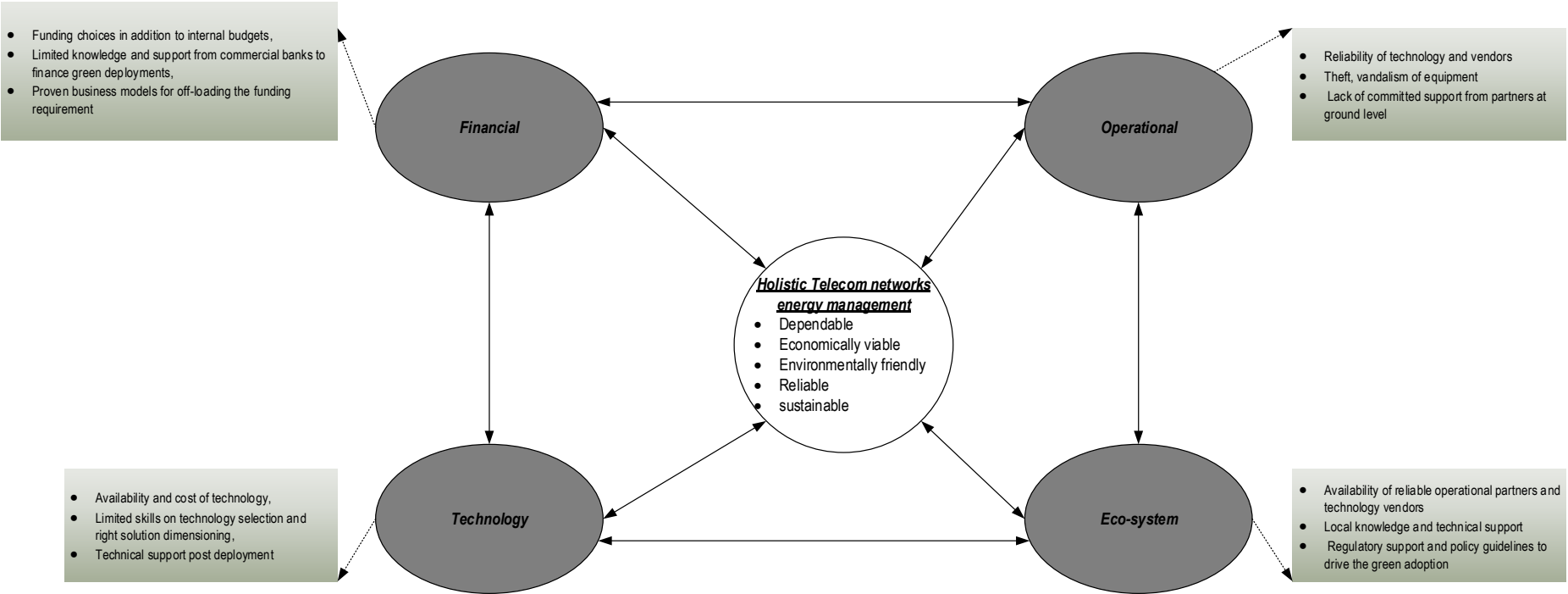


Figure 2. Proposed systemic context diagram for guiding telecom networks energy management

Possible applications of the framework. We trust that the proposed conceptual framework will give valuable clues and guidelines to decision makers, researchers and analysts involved in energy planning, management and implementation programs especially in the resource constrained remote areas of sub-Saharan Africa dominated by off-grid power status. We also believe that it can provide a useful guideline for undertaking analysis of dynamic processes that contribute to a transition to a low carbon economy. Similarly, the framework can be used to evaluate the implications for economic growth and development of transitioning to a low carbon economy. Lastly, the proposed conceptual framework will assist in the analysis of mutual causal influences amidst systems, thereby verifying the relative causal efficacy of different technical, natural and social factors in relation to energy management of telecom networks across SSA.

Conclusion

Sub-Saharan Africa portrays a big potential of adopting sustainable energy management approaches in telecom networks so as to address the current telecom network energy related challenges. Financial, technical, operational and ecosystem factors have handicapped the scale of greening in SSA telecom networks over the past years. There necessitates a systematic and holistic intervention in order to catalyze and drive the growth of better energy management approaches, for example adoption of green power alternatives across SSA. A systems approach by the industry, and all stakeholder groups could drive the adoption of cost effective energy management approaches to address the current energy challenges, including further growth of capacity and coverage compared to the current reductionist approach. In consideration of this, this paper proposes a holistic inter-disciplinary conceptual framework for guiding stakeholders involved in the planning and management of sustainable energy.

This paper is based on a PhD research work in progress. The concept in this paper will, as the next step, be complemented and improved by field research, interactions and discussions with experts dealing in telecom power/energy solutions. This will form one of the steps in the formulation of a novel framework for managing energy in telecom networks across SSA.

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