Uncharted Academic Waters: A Case for mUtilities (Energy, Water and Sanitation)

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ABSTRACT This paper aims to explore the academic literature in Information and Communication Technology for Development (ICT4D). It seeks to find out how Information and Communication Technology (ICT) and mobile technologies have been used to enhance the provision of utility services (energy, water and sanitation). We systematically searched through 1263 academic research papers from five top ICT4D journals and one Mobile Communication for Development conference series over the last decade (2008-2017). Only six papers were found to have discussed the use of ICTs in the provision of utility services in a broad way. This dearth of academic research moved us to further explore how practitioners have handled research in the same field. The literature from practitioners shows a lot of potential in the use of mobile technology in supporting the infrastructure used to provide utility services, because most of the people lacking these services are connected to the mobile infrastructure. Their access to the mobile network presents an opportunity to innovate and leverage on the mobile technology and infrastructure to efficiently provide these utility services. Companies leveraging mobile technologies to provide utility services have also attracted significant funding in the recent past, demonstrating investor confidence in this sector. We therefore present a case for the inclusion of mUtilities as a viable empirical testbed within the M4D and ICT4D academic literature.

Keywords: M4D, ICT4D, mUtilities, Energy, Water, Sanitation, PAYG Solar

1. Introduction

From the global Millennium Development Goals (MDGs) to the United Nations' Sustainable Development Goals (SDGs), alleviating poverty in all its forms and dimensions, including extreme poverty, remains the cross-cutting aim (United Nations, 2015; Heeks, 2014)

At the moment, major groupings have already been made within the academic literature on ICT4D and its subset, Mobile Communication for Development (M4D). The groupings have revolved around health, education/learning, agriculture, commerce and governance. These groupings have given rise to the ePhenomenon and mPhenomenon for example eHealth, eLearning, eAgriculture, eCommerce and eGovernance, plus their equivalents in mobile technology. Other additional groupings have also emerged within ICT4D academic literature, albeit at less frequency for example mInclusion, mEmpowerment, mInnovation, mLivelihood and others.

On closer examination, the major groupings are in line with specific SDGs and MDGs. Table 1 shows the groupings and their corresponding SDG and MDG.

Table 1: ICT4D/M4D groupings and their corresponding MDGs and SDGs. Source: Authors' Conceptualization

	ICT4D/M4D Groupings	Corresponding MDGs and SDGs
1.	eHealth/ mHealth	MDG 4 - To reduce child mortality; MDG 5 - To improve maternal health; MDG 6 - To combat HIV/AIDS, malaria, and other diseases SDG 3 - Good Health and Well-Being for people
2.	eLearning/ mLearning	MDG 2 - To achieve universal primary education SDG 4 - Quality Education
3.	eAgriculture/ mAgriculture	MDG 1 - To eradicate extreme poverty and hunger SDG 2 - Zero Hunger
4.	eCommerce/ mCommerce	MDG 1 - To eradicate extreme poverty and hunger SDG 8 - Decent Work and Economic Growth
5.	eGovernance/ mGovernance	MDG 8 - To develop a global partnership for development SDG 16 - Peace, Justice and Strong Institutions; SDG 17 - Partnerships for the Goals

1.1 – Utility (Energy, Water and Sanitation)

The Oxford Dictionary defines Utility as "an organization supplying the community with electricity, gas, water, or sewerage". Utilities therefore, are key players towards the achievement of SDG 6 – Clean Water and Sanitation; and SDG 7 – Affordable and Clean Energy.

Achievement of SDG 6 and/ or SDG 7 will have a catalytic effect of enhancing the achievement of the other SDGs. On the contrary a lack of access to modern energy can confound a country's efforts to tackle its challenges, such as poverty (SDG 1); food production and security (SDG 2); air pollution, low levels of life expectancy and lack of access to essential healthcare services (SDG 3); delivering quality education (SDG 4); gender inequality (SDG 5); economic growth and employment (SDG 8); sustainable industrialisation (SDG 9); and adaptation and mitigation of climate change (SDG 11). This affirms the importance of access to modern energy services and the centrality of energy in achieving many of the other SDGs (United Nations, 2015; United Nations, 2016).

The United Nations (n.d. a) reported that 1.2 billion people globally do not have access to the electricity grid. This translates to one in every five people. About 95% of them live in sub-Saharan Africa (598 million) and South and East Asia (571 million) (BNEF & LG, 2016) . It is also estimated that another 1 billion people globally are connected to the grid but suffer from unreliable service levels. Another 2.8 billon people globally rely on wood, charcoal and coal for cooking and heating, which results in over 4 million pre-mature deaths per year due to indoor pollution. Without electricity, women and girls spend hours fetching water, clinics cannot store vaccines for children, many school children cannot do homework at night, and people cannot run competitive businesses (ibid).

Even though access to water, sanitation and hygiene is a human right, billions of people globally are having problems accessing the most basic of these services. The United Nations (n.d. b) reported that about 1.8 billion people worldwide use a source of drinking water that is faecally contaminated. 2.4 billion people lack access to basic sanitation services such as toilets and latrines. 40% of the world's population are affected by scarcity of water and this population is projected to rise.

Water and sanitation related diseases are reported to be a major cause of death in children under the age of five years. More than 800 children die daily from diarrhoeal related diseases. Two million people die every year from diarrhoeal diseases, of which 90% are as a result of poor hygiene and unsafe drinking water (ibid)

It is rather peculiar that, of the 1.2 billion people without access to the electricity grid, 855 million of them have access to 2G or 3G mobile networks (GSMA, 2018). Of the 848 million people without access to water, 373 million have access to 2G or 3G mobile networks. Similarly, of the 2.4 billion without access to basic sanitation, 1.97 billion have access to 2G or 3G mobile networks (WHO, 2017). This access to the mobile network presents an opportunity to innovate and leverage on the mobile technology and infrastructure.

Practitioners within the mobile network industry, utility service providers, impact investors, venture capitalists and international development organizations have partnered and created solutions to address the challenges and tap to the opportunities presented. There has been concerted efforts made by the different partners towards using mobile technology to increase access to energy, water and sanitation to the underserved. On the path to accomplishing this, considerable knowledge has been generated by the practitioners. In contrast, there is a dearth of knowledge around these utility services from academic literature within ICT4D or M4D.

2. Objectives

The goal of this paper is to systematically explore the academic literature in M4D and ICT4D to find out how ICT and mobile technology have been used to enhance the provision of utility services (energy, water and sanitation), in relation to development. We aim to present a case for inclusion of mUtilities as a viable empirical testbed within the M4D and ICT4D academic literature.

3. Methodology

For this paper, we employed Systematic Literature Review (SLR). SLR is a specific research methodology developed in order to gather and evaluate the available evidence pertaining to a focus topic (Biolchini et al, 2005) as reported by Touray et al (2013).

We limited the scope of our study to top ICT4D journals only, because they have a rich database of ICT studies that are related to development. We included the top 5 open access ICT4D journals according to Heeks' (2010) ranking that was based on citation rates. The included journals are: Information Technology for Development (IT4D), Electronic Journal of Information Systems in Developing Countries (EJISDC), Information Technologies & International Development (ITID), Asian Journal of Communication (AJC) and African Journal of Information & Communication (AJIC). In our study, we also included conference proceedings of the International Conference on M4D Mobile Communication for Development series.

Our inclusion criteria was: studies that are either research papers or articles that were published in the five journals or one conference between January 2008 to December 2017, and were addressing the use of ICTs in energy, water or sanitation sectors in a broad way. Only literature published in the last decade was considered for analysis because this ensures that the study represents an up to date view of the current state of research (Johnston et al, 2015) in this case, ICT interventions related to energy, water and sanitation.

Consequently, we excluded the following studies that were present in the journals and conference proceedings: reports; editorials; thematic reports; tributes; notes from the field; practitioner tracks; view from practice; legislative reviews; institutional reviews; forums; panels; case notes and book reviews.

3.1 – Our Review Process

In order to allow for replicability of our study and to apply rigour in our methodology, we iteratively followed the steps below:

1. Accessed the online repositories of the included journals and conference series.
2. Applied the following search phrase “ENERGY” OR “WATER” OR “SANITATION” OR “ELECTRICITY” OR “SOLAR” OR “UTILIT*” in the digital archives of IT4D, EJISDC, ITID and AJC. The filter was case indiscriminate. We delimited the results to only include articles that were published between January 2008 and December 2017.
3. From the search results, we then looked at the title and skimmed through the abstracts of each of the results. If the information from the title and abstract was unsatisfactory in providing the empirical setting of the paper, we then skimmed through the full paper text to deduce this information. Based on the scanning and skimming, we decided whether or not the study qualified to be included for review.

We iterated through these steps until all the four journals were exhausted.

For the AJIC, there were a lot of search results from the university website that hosts the journal. This is because it was linked to the Google search engine. We decided to manually access all the online issues of the journal from the year 2008 to 2017 without using the search terms. We therefore moved straight to the third step of our iterative process, scanning and skimming through the title, abstract and full paper text if need arose.

For the M4D conference series, all the five conference proceedings were in Portable Document Format (PDF) . Therefore, applying the search phrase in the second step of our iterative process proved futile. As a result, we also decided to manually scan and skim through all the titles, abstracts and full paper texts where need arose.

With this systematic search process resulting in only a handful of articles meeting the inclusion criteria (Six articles), we resorted to practitioner-based literature, to give inspiration to the future possibilities that academic literature in this sub field could take. These practitioner publications that are dedicated to utility services included GSMA M4D Utilities and Global Off-Grid Lighting Association (GOGLA).

4. Results and Analysis

Table 2 shows the number of research articles published by the top five journals and the M4D conference series from the year 2008 to 2017. Table 3 shows the total number of articles returned from our search queries and the articles that we considered for review in this study. Of the 1263 research articles that were published in the five top ICT4D journals and one conference series, only six articles addressed ICT usage in either energy, water or sanitation sectors in a broad way.

Joo and Kim (2016) examined the factors influencing the adoption and diffusion of the smart grid from the perspective of users and provided strategic guidelines for government and providers. They conducted in-depth interviews with users of the smart grid in the Jeju test bed in South Korea, the world's largest community with smart grid. They analysed data by applying grounded theory. They argue for smart grids as the next generation of intelligent electric power grids by incorporating ICT into existing power grids for optimisation of energy efficiency and utilization. Their study does not touch on the mobile technology.

Table 2: Research articles published by top 5 ICT4D journals and M4D conference proceedings between the year 2008 and 2017

Year of Publication/ Journal Name	**IT4D**	**EJISDC**	**ITID**	**AJC**	**AJIC**	**M4D CONFERENCE**
2017	28	51	13	38	6	
2016	36	50	15	33	20	20
2015	30	46	13	34	17	
2014	14	48	13	34	-	28
2013	15	26	16	35	8	
2012	17	43	23	32	8	62
2011	13	33	16	32	-	
2010	15	33	20	28	4	21
2009	15	33	18	25	4	
2008	15	20	8	23	5	10
Total Number of Research Articles Published	**198**	**383**	**155**	**314**	**72**	**141**

Table 3: Number of research articles that met the inclusion criteria against the search results and the research articles published

Journal Name	**IT4D**	**EJISDC**	**ITID**	**AJC**	**AJIC**	**M4D**	**TOTAL**
Research Articles Published Between 2008 - 2017	198	383	155	314	72	141	**1263**
Research Articles in the Search Results	117	157	78	57	*	*	
Articles addressing the energy, water or sanitation sectors.	**1**	**1**	**1**	**0**	**0**	**3**	**6**

Nganyanyuka et al (2017), focused on a mobile- phone based ICT platform. They proposed and tested an approach to monitor and repair rural water points in three villages in Tanzania, through a mobile based ICT platform. They carried out their research using in-depth interviews in the local dialect (Swahili), participant observation and informal interactions in the markets (having lived there for eight months).

Dasuki and Abbott (2015) used Luke’s concept of power and Sen’s Capability Approach to create a framework to understand the social powers that inhibit or enable individuals from taking full advantage of ICT resources for furtherance of their lives. They illustrate the framework’s utility with a case study based on empirical work in the Nigerian Electricity sector. They used in-depth semi-structured interviews, observations and document analysis to carry out a case study on a Computerised Electricity Management System that among other features, allowed customers to pay their electricity bills using their mobile phones. Their main focus however was not on the mobile component.

The M4D conference proceeding accounted for half of the academic research papers that met our inclusion criteria (three out of six papers). Hellstrom and Jacobson (2014) through an in-depth analysis of four cases, sought to understand the common benefits and challenges for increased and sustainable use of mobile applications in the provision of water services. They contended as a study limitation that use of ICT and mobile in the water sector was a relatively new phenomenon and many projects were still in an early stage of implementation. They conducted their studies in Kenya and Uganda. They however did not provide a specific theoretical underpinning to their study.

Herard and Richomme (2014) present a description of a complete low-cost open-source sensor network solution from the sensor to its associated framework. They describe two use cases where Sensonet has been deployed: in a water survey where a sensor network has been designed in order to automatically retrieve the level of the water sources in Sahel region in order to optimize the path of nomadic farmers. It has also been deployed on solar panel monitoring in schools in Niger. The maintenance is realised by a central entity located in the capital. The sensor network checks that the remote panels are still working and alert, it if is not the case. The paper is quite technical, describing the architecture and overview of the machine-to-machine solution. The paper however lacks the link of how the solution actually leads to development.

Lastly, Sundharam et al. (2012) present a mobile application that can calculate energy consumption and savings by a user in terms of monetary values and carbon footprints. It is also a technical, systems development paper that describes the functionalities and anticipated advantages of the application. The authors have however done less to argue about development or used any theories to explain their work.

Most of the other search results were excluded from this review because they only tackled energy, water or sanitation in passing, or as a requirement or challenge in the field. It is only the six papers that handled in a broad way, the link between ICTs and energy, water or sanitation.

Academic research in this area is still at its embryonic state (Etoundi et al., 2016). This is demonstrated by the handful research articles in the top ICT4D journals. It is also in line with a list of ICT research domains in Africa reported by IST Africa (2012). IST Africa reports that many African countries focus their research efforts in health sector, in technology enhanced learnings, in networks, in digital libraries and in agricultural sector. It seems ironical that as 13 countries are interested in network technology, only two consider the energy sector is an important issue that should be addressed. Less than 20% of African families are connected to the electricity network and therefore, the energy sector should be one that researchers should address as a matter of priority (ibid).

This dearth of academic literature on ICTs transforming the energy, water and sanitation sectors, provides an opportunity to make a case for inclusion of mUtilities as a viable empirical testbed. The next section describes the status of the field in practice and what the academia can learn and borrow from practitioners, moving into the future.

5. Insights from Practice

The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with almost 300 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The Mobile for Development (M4D) utilities programme within GSMA works with any energy, water or sanitation service, provided to a community, which includes a mobile component (voice, Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), Machine -to-Machine (M2M), Near Field Communications (NFC), a mobile operator’s agent network, tower infrastructure). It aims to leverage mobile technology and infrastructure to enhance affordable and reliable energy, clean and safe water and sanitation services in underserved communities (GSMA, 2018).

Through the support that they have received from the government of the United Kingdom (UK) through the Department for International Development (DFID), Scaling off -grid Energy by USAID, Power Africa, Shell Foundation and The African Development Bank (AfDB), GSMA M4D Utilities has extended energy access to 20 million households across Sub Saharan Africa through off-grid household solar solutions.

One can own a mobile phone yet lack basic amenities such as reliable energy to light the house or power business, safe drinking water or household sanitation. These amenities are vital for any individual’s well-being and socio-economic development, but universal access is far from reality. Widespread availability and the rapidly growing markets for mobiles has presented a key opportunity to address the gap.

Business models have ‘matured’ and they combine a variety of mobile channels to deliver essential utility services particularly mobile money, M2M communication and mobile services. It is appealing to the Mobile Network Operators (MNO) and utility service providers to help achieve a social goal (SDG 6 and 7) while also achieving a commercial purpose. The partnerships between MNOs and utility service providers helps improve the lives of the underserved customers; stimulates the markets; and empowers small businesses and saves lives.

Since the year 2012 when the M4D Utilities programme began, 43 organizations have been awarded grants from the Innovation Fund. 25 working on energy, 13 working on water and five working on sanitation. So far, there has been two phases of grants with another three on the way. In the first phase, GBP 2,589,784 was awarded. The second phase saw an increase in the award money to GBP 3,426,470. So far, GBP 1,600,000 has been committed for the phase three grants.

In addition to the grant awards, the grantees have attracted additional USD 275 million in investment from the private sector. This demonstrates the opportunity seen by private investors. The initial grant was towards early stage firms to demonstrate proof of concept for their models in order to attract additional funding. Most of the investment went towards Pay-As-You-Go (PAYG) solar companies with Lumos leading with USD 90 million and M-KOPA following with USD 80 million. The grant projects have demonstrated that improving access to energy, water and sanitation also helps improve health, education, income generation and other areas that enhance the lives of underserved people.

The M4D Utilities programme has managed to publish 17 case studies. It has funded projects and studies in 27 countries: one Latin American, one Oceanic, eight Asian and 17 African. They have concluded market assessment studies for MNOs in nine countries and have approximately impacted 4,542,410 direct beneficiaries.

From evidence, it is reported that digitising utility companies can lead to improvements in the efficiency of water delivery, overcoming the challenges such as bill payment and collection, reliability and improving customer service. Mobile technology is seen as a platform for accelerating progress on the SDGs. In the developing countries, rapid growth of the mobile industry has outpaced the growth of infrastructure and services that are essential for economic growth.

5.1 – The Pay-As-You-Go Model

PAYG refers to a conglomeration of technologies, payment arrangements, ownership modes and financing structures that allow the end user to pay for a solar kit in instalments. The embedded M2M connectivity disables the system if a payment is overdue (GSMA, 2016; M-KOPA, 2016)

The customer typically makes an initial payment of around 30 USD from a sales location for a basic Solar Home System (SHS) that consists of a Photo Voltaic (PV) panel, a battery and a control unit, two or three Light Emitting Diode (LED) bulbs, a phone charger and sometimes other appliances. The customer then makes regular payments (daily top-ups/ credits) of 0.30 - 0.50 USD per day to access the services. They are also allowed to buy credits in any amount, from a single day to 30 days or more. After the customer pays 365 credits, the system automatically switches to free use, requiring no further top ups. The customer then owns the system (M-KOPA, 2015; BNEF & LG, 2016; GSMA, 2017).

The cost is normally calculated so that it is competitive with the daily expenditure on stop gap technologies, such as candles, allowing customers to save from day one. This however applies only to the most common types of SHSs. The payments are mostly made via mobile money although there are alternative ways, such as scratch cards, direct cash payments or using mobile phone credit. If the account is empty or in arrears, the SHS will not discharge power until a payment is made.

PAYG customers under a lease-to-own model may also make use of the PAYG activation technology to collateralise the asset once all payment is made. This will enable them to purchase additional solar capacity, more appliances on offer like smart phones or smart television sets or even non-electrical products like water tanks or energy saving cook stoves. If another product is purchased, the system is closed and top-ups are re-introduced until the full payment is made once again (BNEF & LG, 2016; M-KOPA, 2016; M-KOPA, 2015).

Proliferation of mobile phones in low income economies has been a major driver behind PAYG model. The number of people who own mobile phones far out strips those with access to other services such as grid power and banking (M-KOPA, 2015). The addressable market for PAYG solar solutions remains largely untapped. GSMA (2017) estimates that two thirds of the 1.2 billion off grid population are covered by mobile connectivity. This presents an exciting opportunity to redesign solutions for people who are invisible to traditional service providers.

The PAYG solar sector allows lower income customers to buy solar products on credit and pay small fees for continuous use. By mid-2017, over 1.6 million PAYG solar units had been sold, having been an increase from 800,000 units that had been sold by 2016. Table 4 shows the distribution of the cumulative sales of PAYG units in 2016 and 2017.

Table 4: Distribution of cumulative sales of PAYG solar units in 2016 and 2017. Source: GSMA 2018 Annual Report (GSMA, 2018)

Year	PAYG Solar Units	East Africa	West Africa	South Asia	Latin America
2016	800,000	92%	4%	3%	1%
2017	1.6 Million	83%	11%	3%	4%

There has been impressive scale in the sales, with the West African market improving at a faster rate followed by Latin America. As a result, 8.5 million individuals had benefited from clean and reliable energy in their homes.

The PAYG solar sector is advancing as displayed by the large amount of private capital invested recently to several key players. The PAYG model relies on debt financing to offer SHS on credit. In the early stages, raising capital from risk-averse lenders proved to be difficult. However, in 2016 and 2017, the positive performance by PAYG companies has begun to reverse the trend.

Bloomberg New Energy Finance (BNEF) reported that USD 380 million had been invested in PAYG solar companies in 2016 in debt, equity and grant capital and in 2017 brought additional investments of up to USD 100 million. This attraction of huge capital by companies demonstrates that investors are recognising the commercial promise by the sector. There is now a large community of international funders (17 foundations, 21 impact investors and a number of venture capitalists).

The PAYG market is most advanced in sub-Saharan Africa. The offerings are most common in Kenya, Tanzania, Rwanda and Uganda where market leaders such as M -KOPA, Mobisol, Off-Grid Electric, Fenix International and BBOXX operate (GSMA, 2015; GSMA, 2016). In West Africa, Nova Lumos, PEG Ghana (an M-KOPA franchisee) and Oolu Solar are preparing for growth in Nigeria, Ghana and Senegal respectively (BNEF & LG, 2016; GSMA, 2017).

The success stories in the sector are still being confined to East Africa, with providers looking at the emerging West African market. The Asian markets have important differences and challenges. They have high levels of competition from commodification of the market and a mobile money ecosystem that is either nascent or based on Over the Counter (OTC), in which customers make payments through agents rather than through their own mobile wallets. This presents an opportunity for academicians to help understand the underlying reasons behind this.

5.2 – Emerging Trends in the PAYG solar sector

PAYG companies offer follow-on financing schemes and new products for customers after paying up for the SHS. These new products include televisions, radios, larger appliances, water filters, better cookstoves. This arrangement also reinforces the sales made by the PAYG providers. Financial services, including loans and insurance are also provided to the customers.

Based on customer data and payment histories, credit scoring is enabled. Fenis offers customers access to financing for school loans while PEG offers health insurance.

There is growth of MNO-led business models for PAYG solar and grid mini power. With over 1.6 million mobile money transactions recorded per month on top up PAYG products in September 2016 (GSMA, 2018), the direct benefits to MNOs are clear. MNOs around the world are showing interest in launching their own PAYG solar models as well as smart metering and pre-paid energy platforms for centralised urban grids and mini-grids.

Orange has a mobile enabled grid management system in Tunisia and wants to replicate it in Burkina Faso. Dialog Sri Lanka is working with the national energy utility, Lanka Electricity Company (LECO), to develop a pre-paid metering solution. There is potential to test the potential of MNOs embracing the opportunity to become the driving business entity for launching and scaling these models. There is need to better understand the true commercial value of these services for the MNOs. There is also need to test whether MNOs' brands and vast customer networks can scale these services at rapid rates.

All these emerging trends in the mobile and utilities sector present vast opportunities for research in related academic spheres.

6. Conclusion, Limitations and Future Directions

This paper reveals a dearth of academic research into the area of ICT use in provision of utilities (energy, water and sanitation services). It presents the academic research landscape within this area over the past 10 years (2008 - 2017), with the intention of proposing ways to fill the gap. Of the 1263 academic articles that were the subject of this study, only six discussed ICT usage in the energy, water or sanitation sectors, in a core manner. This demonstrates that very little academic research exists in this area. However, on a positive note, it provides a great opportunity for future research.

We are in agreement with Strand (2016) that since this is an emerging field with low level of maturity, the review process was further complicated. It could be argued that a less formalistic review design may have resulted in a larger body of academic research to analyse. Future research analysis should include other publication platforms including but not limited to database searches, influential reports from the development community, conference papers, sector-relevant edited books and chapters.

Moving into the future, academic research in this area can borrow a leaf from the practice in the same field, which is evidently more advanced. The practitioner research in this field points to gaps and opportunities which can be addressed by academic research. There is also potential for academic research to inform policy in this area.

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