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Editorial

Microgrids for Productive Uses of Energy in the Developing World and Blockchain: A Promising Future

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Currently, 1.06 billion people still do not have access to electricity, with the majority living in rural areas around the world [1]. In Sub-Saharan Africa alone, the electrification of rural areas is only at 19% [2]. Non-access to electrical energy and poverty are closely related; electricity is an invaluable input for economic development. Microgrids are becoming a key player for cost effective and reliable electrification of rural areas, and it is projected that one-third of the total investments towards achieving the 2030 Sustainable Development Goals (SDG) of the United Nations for universal access will be targeting microgrids, powered mainly by renewables [1]. Moreover, in Sub-Saharan Africa, off-grid systems are projected to provide access to nearly 65% of the newly-electrified population [3].

Autonomous microgrids can provide power, not only for residential loads, but they can also effectively power a vast array of apparatuses and equipment, directly associated with economic development, such as water pumping, water desalination, refrigeration, space heating and cooling, incubators for poultry farming, milking machines, rice and maize hullers, polishers, threshers, graters, grain mills, oil presses, tailoring, workshop machinery (e.g., drills, chainsaws, rotary hammers, grinders, jigsaws, routers, etc.), hairdresser equipment, etc. [4]. These productive uses of energy can become a development force in rural areas of the developing world. Microgrids also employ a number of smart sensors and actuators for the implementation of advanced energy-management systems and demand side management schemes [5,6]. These components of a microgrid usually communicate by employing Internet of Things paradigms [7] and wireless networks [8]. This infrastructure can be further utilized for the provision of wireless Internet at the same time, creating new possibilities for the provision of extended services based on Internet access [9].

A number of business models are evolving in order to effectively finance and operationalize microgrid operators that are, not only power producers and providers, but also suppliers of services based on electricity. This diversification of products and services is an important tool in the hands of project developers for decreasing investment risks [10]. The use of the pay-as-you-go model in conjunction with smart meters and Internet platforms has been gaining momentum and utilization [11]. Such platforms are expected to be expanded in order to facilitate access to, and payment of, services provided by a microgrid operator, realizing a local virtual marketplace.

The solar home systems market in Sub-Saharan Africa has been booming recently. Only in the first half of 2017, 1.77 million products, pico photovoltaics (PV) and Solar Home Systems (SHS), have been sold in Sub-Saharan Africa, with corresponding cash sales revenues of 40.67 million USD [12]. Many of these systems in rural areas of the developing world are in areas where microgrids will be deployed in the coming years. Smart interconnection of these systems will be beneficial, both for the owners of these systems, as well as the microgrid operators. A typical scenario would be the sale of electricity during mid-day, when the battery of a solar home system is full, and the purchase of extra electricity during the night, when the SHS battery is discharged. Such activities create the need for a virtual marketplace to be able to accommodate and facilitate two-way transactions, purchases and sales.

Blockchain, according to Reference [13], can be defined as "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way". It gained mainstream attention in 2009 through its application to BitCoin, which was the first open-source, peer-to-peer, digital, decentralized cryptocurrency. The applications, though, of blockchain surpass digital currency and go beyond affecting different realms of our daily lives [14]. The applications in the energy field have been gaining attention, starting from research [15,16] leading to demonstration projects by start-ups [17], which have caught the attention of traditional electrical industry actors [18]. A distinction has to be made between permissioned or private blockchains and premissionless or public blockchains, and it has to be mentioned that the private blockchains are usually called "distributed ledgers" [19]. A comparison of permissioned and permissionless blockchains is made in Table 1.

Table 1. Permissioned vs. permissionless blockchains [19].

	Permissioned or Private Blockchain	Permissionless or Public Blockchain
Network access	Authorized access	Open access
Approach in relation to laws and regulations	Able to comply with "Know Your Client (KYC)" and "Anti Money Laundering (AML)" banking regulations	Aims to create censorship resistant anonymous transactions outside of the current legal and regulatory framework
Validator approach	Pre-selected trusted validators	Anonymous, fully decentralized validators

Blockchain, in principle, could provide a solution for the creation of a virtual marketplace in rural areas of the developing world, since it can cover the scenarios analyzed previously. While many blockchain applications have been proposed for grid-connected systems, there is a lack of applications for off-grid systems. Most current blockchain applications need uninterrupted access to the Internet. While this can be taken for granted in grid-connected scenarios, most locations in the developing world have either no Internet access or the access through mobile telephone networks is intermittent, characterized by very low connection speeds and low-quality connections. In theory, a blockchain could be realized in a local network, but a minimum number of computers have to exist in order for decentralized verification of transactions to take place. Processing power in rural areas of the developing world is scarce, and consists mainly of smartphones. New research has to take place in order to decrease the decentralized processing power needed by a blockchain in such a reality. New private blockchain verification algorithms, with the use of pre-selected trusted validators, could be one of the ways forward. Moreover, increasing interest is drawn to the combination of the Internet of Things with blockchain applications [20]. Potentially compatible sensors, actuators and devices in microgrids could be used as nodes of a blockchain.

Digital technology applications, such as blockchains, can facilitate the deployment of microgrids in the developing world and contribute to achieving the 2030 SDG of universal energy access. The future looks promising.

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