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# Real Time Monitoring Technologies for Pro-Poor Access to Electricity

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July 2013

The IDS programme on Strengthening Evidence-based Policy works across seven key themes. Each theme works with partner institutions to co-construct policy-relevant knowledge and engage in policy-influencing processes. This material has been developed under the Policy Anticipation, Response and Evaluation theme.

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# REAL TIME MONITORING TECHNOLOGIES FOR PRO-POOR ACCESS TO ELECTRICITY

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# Contents

# List of Abbreviations

| | |
|---|---|
| ESCOs | Energy service companies |
| GSM | Global System for Mobile Communications |
| HTTP | Hypertext Transfer Protocol |
| M2M | Machine to machine |
| RDS | Routine data systems |
| RTM | Real time monitoring |
| SHS | Solar home systems |
| SMS | Short Message Service |

# 1 Introduction

## 1.1 Real time monitoring in the context of affordability and financial sustainability of electricity for the poor

Existing literature strongly and consistently reports the high upfront cost of energy technology hardware (for both on-grid and off-grid electricity) as one of the main demand-side barriers to increased use of modern energy services by the poor (Watson *et al*. 2012). This economic barrier comes together with the lack of access to finance for the poor (Louw, Conradie, Howells and Dekenah 2008; World Bank 2008). Existing literature also shows that lack of control over monthly bills and unawareness of consumption levels lead to inefficient and sometimes insufficient electricity consumption patterns by the poor (Ilskog, Kjellström, Gullberg, Katyega and Chambala 2005; Peters, Harsdorff and Ziegler 2009)

On the supply side, there is strong evidence of suppliers' difficulty in recovering the costs of electricity supply to low-density, poor and/or remote populations or of illegal connections in rural areas and slums (Watson *et al*. 2012). Consequently, many donors such as USAID and the World Bank target their rural electrification efforts to those communities with the highest cost-recovery potential on the basis of distance to the existing grid, population size, affordability (average community income) and productive potential (World Bank 2008). As a result, many rural areas and slums remain underserved or dependent on dangerous and unreliable connections.

Some traditional interventions to deal with the barrier of affordability of electricity are finance and credit for the poor or subsidies. However, centralised government or NGO programmes that are target-oriented and subsidy-driven have been criticised in the literature for their inability to create awareness among users, limited outlets of procurement, insufficient adaptation of technology to local needs, and their creation of market-distorting behaviour (Rehman *et al*. 2010). Heavy subsidies to electricity tariffs are also behind the dire financial condition of many electricity utilities in developing countries and often are not necessary or benefit only the better-off (Dube 2003; Ilskog *et al*. 2005; Kemmler 2007). Cross-subsidies can also excessively penalise industry in favour of households, making industry opt for its own generation systems to avoid high tariffs and unreliable service (Asian Development Bank 2005). This reinforces the financial unsustainability of the grid system and contributes to the inefficiency of electricity provision in a country.

Innovative technologies drawing from existing power metering and mobile payment technologies are targeting the barriers of affordability and financial sustainability of electricity provision to the poor by allowing fee-for-services and rent-to-buy schemes for the sale of electricity, tariffs related to actual consumption, consumers' control of their electricity bills and suppliers' more efficient collection of payments. Real time monitoring (RTM) of on-grid electricity consumption has a long history, with prepaid meters being used in several developed and developing countries. However, new mobile technologies are enabling their use in off-grid systems, including both mini-grids and mobile household systems.

Much of the recent initiatives using mobile technologies to support the provision of electricity to the poor have been driven by the astonishing speed at which mobile phones have spread throughout the poor communities of the developing world, without the need for subsidies or other donor-driven initiatives. According to Nique and Arab (2013: 4):

> The number of mobile connections in the developing world has risen from 2.14 Billion in 2007 (38.2% of market penetration) to 4.96 Billion in 2012 (83.4% market penetration). Today 3 of every 4 new connections is occurring in the developing world. Africa was the second largest mobile market in the world, after Asia. Sub-Saharan Africa in particular is the fastest-growing mobile market, with an average annual growth rate of 44% since 2000, reaching 64% mobile market penetration in 2012.

This means that more people now have access to mobile networks than they have access to electricity, with an access rate of 43 per cent in Africa (IEA 2012).

According to GSMA, the significant growth in mobile subscribers in Africa has been driven by, among others, the introduction of low-cost handsets, the reduction of mobile usage prices and the provision of prepaid services that allow consumers to take control of their spending and make up 96 per cent of African connections (GSMA 2011).

Several initiatives for the provision of electricity to the poor are trying to replicate these success factors of mobile services making use of advanced RTM technologies to monitor electricity consumption and enable flexible prepaid services. The aim of this report is to take stock of the different initiatives in place, analyse the existing evidence of their success in increasing access to electricity for the poor, and draw policy conclusions on how the data collected can improve the performance of electrification programmes.

## 1.2 RTM in the context of previous IDS work on vulnerability

IDS has carried out extensive research on real time monitoring technologies for the most vulnerable. According to IDS's previous work (IDS 2012), RTM is defined as meeting two key characteristics: its higher frequency relative to traditional data and the generation of a response. IDS RTM research has so far focused on data on risk, vulnerability and access to services among vulnerable children and populations and on the stability and security of livelihoods affected by shocks. In the desk review carried out for UNICEF on 'Real Time Monitoring for the Most Vulnerable', IDS looked in particular at routine data systems (RDS) as a primary source of timely information on the provision of health, education and water (IDS 2011). RDS are relatively inexpensive and generate time-series data that can allow far more persuasive analysis and interpretation than intermittent cross-sectional surveys. Most importantly, they allow a degree of disaggregation by socioeconomic group and geographical location that has the potential to allow users to determine not just that there are problems with service delivery in a given sector but also precisely where provision is failing and which sections of the population are likely to be suffering the greatest impact.

The proposed research complements this aspect of previous IDS research by applying it to a new area: the provision of electricity. RTM for electricity consumption is continuously collected, as opposed to traditional metering where utilities only monitor consumption for billing purposes a few times a year. The generation of a response to data on electricity consumption is not so clear beyond billing purposes. This study aims to analyse the current uses of real time data on electricity consumption for utilities or suppliers of off-grid power systems.

## 1.3 Structure of the report

The report starts by describing traditional and emerging technologies for monitoring, billing and controlling electricity consumption. Section 3 provides an initial inventory of suppliers of these technologies with a special focus on the provision of electricity for the poor in developing countries. Section 4 is a survey of the existing evidence for the success of RTM to improve affordability and financial sustainability of electricity provision to the poor, and hence to increase consumption and connection rates. Section 5 discusses the potential uses of data on electricity consumption and payment patterns by the poor for the improvement of policymaking in the field of pro-poor electricity access.

# 2 Technologies

## 2.1 Conventional prepayment metering for on-grid systems

Conventional prepayment metering systems consist of a smart card or token read and stored within the meter, with the electronic prepaid meter acting as a bank. As long as some credit is available inside the meter the customer will be able to consume electricity. The level of credit inside the meter is deducted according to the tariff as programmed for the particular consumer. When the credit reaches a threshold amount or zero the meter issues warnings. Emergency credit is usually available once the credit is zero and after the emergency credit runs out the service is disconnected until the customer recharges the prepaid meter with a new smart card or token.

The main benefit of conventional prepaid meters for the end-consumer is the ability to control electricity bills and plan the budget required. The main benefits for utilities are the reduction of financial risk and customer debt and the reduced cost of paperwork and meter reading. Some disadvantages of these systems are the additional hardware and maintenance cost, the inconvenience for the customer of frequent trips to top up tokens and smart cards, and the higher price paid compared to direct debit and on-line payment methods (Padmanabhan 2010).

Recent advances also allow a smart on-grid metering infrastructure that transmits interval readings on a daily basis to the utilities. Some benefits of this advanced metering infrastructure are that it allows customers to switch between credit and prepaid meters and change their rate plan when they want. It also enables mobile and online payments, preventing the nuisance of having to carry smart cards or tokens.

## 2.2 RTM solutions for remote monitoring and mobile payment in off-grid systems

Machine to machine (M2M) solutions that allow machines to be connected through a seamless network, coupled with mobile micro-payments, are enabling new business models for the provision of affordable energy to off-grid communities.

M2M technology enables active monitoring of off-grid electricity systems such as solar home systems (SHS) or renewable energy mini-grids. This allows suppliers of energy services or energy service companies (ESCOs) to have real time (hourly or more frequently) information about a number of indicators such as: electricity consumption, renewable energy generation, battery voltage and system failures. These data are stored in a central database that can communicate with customers' mobile phones and meters using Hypertext Transfer Protocol (HTTP) and Short Message Service (SMS) text messaging over the Global System for Mobile Communications (GSM) network. The communication gateway required for communication through SMS between the customer, the server and the meter is provided by the mobile operator or by employing custom software in conjunction with a modem (Nique and Arab 2013).

Mobile technologies allow the integration of mobile money services and energy services. Customers can make prepayments for electricity as they use it, through mobile money applications or by purchasing scratch cards that are validated using SMS. Proper real time solutions are M2M-enabled units with systems remotely monitored over the GSM networks. Payments are made with mobile money, which seamlessly unlocks the micro-utility unit over the air. These systems require reliable GSM coverage and high mobile money penetration. They can be more costly than 'near real time solutions' due to the cost of the GSM module required. Near real time solutions can involve the use of scratch cards with a code that needs to be sent by the user to a central server by SMS. An SMS code is sent back to the user, who types the code on the keypad attached to the energy equipment. The main challenge for this system is ensuring the efficient distribution and stock management of scratch cards (GSMA 2013).

# 3 Business models enabled by RTM

M2M technologies allow business models that address the issues of affordability of electricity for the poor and financial sustainability for service providers. Affordability and financial sustainability have been identified in the literature as two of the main barriers to increased connection to and consumption of electricity for the poor.

Three new business models have emerged that use RTM: mini-grids managed by locally operated ESCOs with monitoring, control and billing through M2M; pay-as-you-go SHS with ownership option; and energy services upgrades.

## 3.1 Mini-grids managed by locally operated ESCOs

The growing use of renewable energy for off-grid mini-grids requires supply and demand balancing to be managed largely by demand dispatchability and battery energy storage (Castillo-Cagigal *et al*. 2011). Unlike conventional fossil-fuelled generators, systems powered by renewable energy cannot respond to variations in demand and require a more sophisticated design and operation, involving the harvesting and analysis of data on end-user behaviour and renewable resource availability to optimise the operation of mini-grids. M2M technologies can support monitoring and control of mini-grids powered by renewable energy sources. They allow generation systems to send operational data so that possible system failures can be diagnosed before they actually occur. They can also enable cashless micro-payments for end-users, thus allowing them to pay for energy as they use it.

Several suppliers identified in our inventory use M2M technologies to monitor, control and bill for mini-grids in developing countries. These include: Access:energy; Bright Solar Power; CAT Projects; Devergy; Gram Power; Lumeter Networks; MeshPower; Off-Grid:Electric; Powerhive; and SharedSolar.

M2M technologies are expected to incentivise not only access to electricity for the poor, but also the emergence of local ESCOs, as the risk of managing mini-grids is reduced through better monitoring and control or remote systems and prepayment possibilities.

Box 3.1 shows the particular case of Access:energy, a company based in Kenya that is using RTM technologies to operate mini-grids.

### Box 3.1 Case study: Access:energy

Access:energy designs and builds micro-grids for remote communities in Kenya. It is developing a number of innovative M-Pesa-based mobile-payment business models to support its micro-grids. It has developed the bitHarvester to monitor and control its systems second to second, reporting data including energy usage and power generated to its central servers using standard SMS text messages.

**How is its technology different from other initiatives?**

All M2M technologies for energy access are very similar, even though they concentrate on different aspects (e.g. systems performance, payments, renewable energy resource). What is particular about Access:energy technology is modularity. The technology has been built to allow plug-in of different modules to power generation and consumption hardware and is applicable to both home systems and mini-grids. The back end is in a cloud.

**Data collected**

Access:energy bitHarvester technology started as just a diagnostics tool to ensure that the generation and storage systems were working well. It now collects data on production, consumption and diagnostics and it can work for both household systems and mini-grids. Access:energy has several sensors at the supply and demand side to collect data on power generated, temperature of the battery, AC power out in each of the users, wind speed and wind power generation. This allows it to collect ever-increasing, high-resolution renewable energy resource data to map the solar and wind resources across East Africa.

**Stage of development of the technology**

Through several iterations it has developed a number of prototypes and finds itself at pre-production stage. Its product is still not sold on the market but it is looking at an ambitious scaling-up plan and is talking to several institutions to deploy its technology. It has found that NGOs and other potential consumers are more interested in the consumer end than in the supply/diagnostics side of the technology

**Business model**

Its business model relies on in-depth knowledge of the local reality and on the ubiquitous mobile phone to interact with consumers. It identifies villages that have the right criteria to install mini-grids, mainly dense communities with an obvious and more or less reliable income stream. It then relies on a local entrepreneur to connect all relevant users and manage the mini-grid. The local entrepreneur buys kWh from Access:energy and final consumers prepay for kWh through mobile payments. Access:energy remains owner of the system, which gives it flexibility to increase or decrease generation capacity to match demand. Connection fees are almost negligible for the final consumer, with up-front costs covered by the local entrepreneur or Access:energy. Final consumers pay only for the energy they use and tariffs are estimated on the basis of willingness to pay and cost recovery. Tariff schemes will also try to incentivise consumers to use more electricity during low load times of the day, so as to optimise the load factor of the system.

**Can the system enable productive activities?**

kWh usage is unlimited for users and should be more than enough to enable most productive activities. The bitHarvester technology will signal if the system struggles to meet demand and in that case Access:energy would add more capacity.

Source: Interview with Sam Duby, co-founder of Access:energy, 27 March 2013.

## 3.2 Pay-as-you-go and lease-to-buy schemes

Pay-as-you-go schemes are used for both home systems (mainly SHS) and mini-grids but lease-to-buy schemes are almost exclusively used by SHS providers.

This business model borrows the idea of the purchase of mobile phones airtime through mobile payments and scratch cards. As with mobile phones, energy users can buy scratch cards to pay for their energy or use mobile payment platforms. If scratch cards are used, the number in the card is validated by sending an SMS to the server of the ESCO and then a pass code is introduced in the household energy system, which allows it to operate for a period of time. The consumer must usually pay up front a fraction of the total cost of the SHS, but the rest is paid through the small instalments that give the consumer credit to consume the electricity generated by the system for a period of time. Usually, after several payments for the energy service provided, once the cost of the system has been covered, the system is permanently unblocked and ownership is granted to the consumer.

Frequent top-ups are essential to guarantee the financial viability of this business model for the energy services provider. Therefore, they must be set at an affordable rate for consumers, which is often estimated taking into account their current energy expenditures in alternative energy sources such as kerosene or candles.

This business model is used by several companies included in our inventory: Angaza, Azuri Technologies, Bright Solar Power, DT Power/Mobisol, Econet Solar, e.quinox, Hessex, Lumos, M-KOPA, SIMbaLink, Simpa Networks, Stima and Sonopro. It is particularly suitable for the sale of SHS, with all the companies above selling these. It removes the barrier of affordability for poor consumers by substantially reducing up-front payments and adapting payments to the actual flow of income of consumers. The main benefit for the supplier is financial sustainability, as revenue collection of small instalments would be a challenge for off-grid household systems otherwise.

Box 3.2 shows the case of Azuri Technologies, one of the most successful innovators using this business model to provide SHS in East Africa.

## 3.3 Energy services upgrades

Azuri Technologies has developed this unique concept through its Indigo Energy Escalator. When the cost of the SHS it provides has been fully covered by several pay-as-you-go instalments, customers can either opt to own the system or upgrade to a larger system. Through this process, customers can start with a 3W system powering two lights and a mobile charging unit, upgrade to a 10W system powering four lights, a mobile charger and radio, move up to a 40W system able to power a TV and eventually reaching full home electrification with an 80W system that also powers productive equipment such as a sewing machine. Customers can stop upgrading at any point they wish and decide to own the system they are using at the moment. This business model is particularly beneficial in that it addresses the problem of lack of productive uses of electricity, which is highlighted as one of the main barriers to poverty impacts of electricity consumption. Through upgrades to larger systems, consumers can gradually afford productive equipment and use electricity for income-generating activities that help them earn their way out of poverty.

### Box 3.2 Case study: Azuri Technologies

**How is its technology different from other initiatives?**

Payment system through scratch cards and SMS enables users to pay for home solar energy services as they use them and access these services at a low upfront cost. After completing payment, users have the opportunity to own the system or go up the Indigo Energy Escalator and upgrade to larger systems.

**Real time data collected**

The technology collects real time information on the frequency and the period of time covered by users' top-ups. Information on the systems' diagnostics, power generation and consumption is not collected remotely but is followed up by distributors in the field.

**Stage of development of the technology**

The technology is commercially available. The company has more than 20,000 Indigo systems installed or in its distribution pipeline. Its geographic focus is sub-Saharan Africa with three distinctive markets: East, Southern and West Africa.

**Business model**

Inspired by the mobile phone market, rural households pay as they go for energy services, similar to 'airtime'. Users make a small upfront payment for the installation and commit to topping up their units by buying scratch cards. The initial commitment specifies the period during which they must buy scratch cards, at the end of which their system can be either unlocked (giving them ownership) or upgraded to a larger system.

Azuri works with local distributors with an in-depth understanding of the market. Local partners are at the front line of distributing, installing and servicing customers, supported by training and guidance from Azuri. At the very initial stages when Azuri is discussing collaboration with these partners, it gains an understanding of affordability for local consumers. Azuri take into account what the market is currently paying for lighting and mobile phone charging and provides tariffs that are cheaper than these. These can vary from market to market. An affordable tariff is key to the sustainability of its business model.

Azuri believes that energy access businesses must be commercially sustainable without external subsidies.

**Connection rates**

Azuri believes the pay-as-you-go business model is able to reach a much higher share of the market than the traditional model of selling solar home systems upfront. This is due to the low upfront cost and ability for customers to immediately start saving, low-risk for customers (where the on-going payments ensure they can access after-sales servicing) and aspirational nature of the energy escalator.

**Productive uses**

All customers are currently using an entry-level solar home system. The energy services provided are lighting and mobile phone charging. The first group of customers have unlocked their systems in Kenya. Impact studies have shown that: households are saving money and time; kerosene use has been reduced and eradicated in many households; and study, family and productive time has increased.

Source: Interview with Selene Gittings, Distribution Systems Manager at Azuri Technologies, 28 March 2013

## 3.4 Energy budgets

This concept is marketed by CAT Projects in its mini-grids projects in India. Each household has a daily energy budget that is programmed in home display and control units. This provides stability to the micro-grids and control to households over their monthly bills. The energy budget is set up in households, community and commercial establishments taking into account several parameters such as building size, occupancy and use, income and expenditure and current energy use. Energy budgets can be changed to accommodate the circumstances of the consumers and they are continuously monitored to ensure that the system capacity can cope with these changes.

# 4 Inventory of suppliers of RTM technologies for pro-poor electricity access

Table 4.1 presents a list of suppliers making use of RTM to provide affordable access to electricity for the poor. The table shows details of the supplier, a description of the RTM and energy generation technologies they use, the energy services they provide, their business model and geographic scope.

A total of 22 suppliers have been identified; 55 per cent use RTM to provide SHS with a pay-as-you-go option, 30 per cent provide access to energy through mini-grids and 15 per cent provide monitoring systems that can be used in both SHS and mini-grids. Whereas SHS have the potential to increase poor people's quality of life, their main drawback is that their small size allows for only a limited number of energy services, mainly lighting and mobile phone charging. Mini-grids enable wider uses of electricity, including productive uses that are considered key to overcoming poverty.

There is a clear geographic focus in East Africa, with 44 per cent of the suppliers, followed by India with 17 per cent. This is probably due to a combination of very low electrification rates and very high mobile services and mobile money penetration in East Africa.

## Table 4.1 Inventory of suppliers of RTM technologies for pro-poor electricity access

| Name of company/product | Real time monitoring technology | Generation technology | Energy services | Business model | Geographic scope |
|---|---|---|---|---|---|
| Access:energy<br><br>http://accessenergy.org/<br><br>Kenya | bitHarvester, a device that transmits energy end-use data such as minute-to-minute power consumption, meteorological data such as wind-speed and direction, performance of the equipment and any failures in the system. A network operating centre constantly monitors, evaluates and controls transmitted data. | Adaptable to any off-grid generation technology that supplies a micro-grid. | kWh | Off-grid ESCO with a pay-as-you-go solution. The ESCO buys energy from Access:energy and then sells it to final consumers.<br><br>Buyers can buy kWh using their mobile phones. | Kenya |
| Angaza Design<br><br>http://www.angazadesign.com/<br><br>USA | Angaza Energy Hub receives customer payments through different mobile money systems across multiple countries; securely and automatically communicates with customers' Angaza solar systems. Real time data only on payments. | SoLite3 Solar Home System, 2W | 8 hours of lighting in normal or 4 hours in high mode, and mobile phone charging. | Small up-front payment and then pay-as-you go solar energy. | Tanzania, Kenya and Zambia |
| Azuri Technologies Ltd/Indigo<br><br>http://www.azuri-technologies.com/<br><br>UK | The Indigo system provides real time information on top-ups: frequency and period of time covered. This links to a metering device integrated in the SHS that blocks the system when the period covered by the top-up ends. | SHS<br><br>3W–80W | Basic system 8 hours of lighting (normal mode) or 4 hours (bright mode) for two rooms and mobile charging. As the consumer upgrades, the system can power other small devices and with enough upgrades, large appliances such as refrigerator or sewing machine. | Small up-front payment, then pay-as-you-go for weeks of light, using scratch cards and SMS service. After around 18 months the customer will have paid off total investment and can either own the system or upgrade to a larger system, through Indigo's energy escalator. | East Africa |

| Name of company/product | Real time monitoring technology | Generation technology | Energy services | Business model | Geographic scope |
|---|---|---|---|---|---|
| Bright Solar Power<br><br>http://www.brightsolarpower.com.ng<br><br>Nigeria | Bright Solar Power Payment System. Their monitoring technology tracks and manages power-generating assets and provides real time data on consumption and payments. | 1,000W solar home generator and solar for community micro-grids. | Satellite antenna, colour TV, computer, lighting, fan, refrigerator, mobile charger, printer, radio. | Small up-front fee and then pay-as-you-go with scratch cards and sending an SMS providing Bright Solar home user certificate number. Consumers can own the system once they have paid off the initial costs. | Nigeria |
| CAT Projects<br><br>http://www.catprojects.com.au<br><br>Australia | The Urja Bandu (or energy friend) is a display and control unit that displays the current availability of the programmed daily budget for each household or business and cuts off power if this budget is exceeded during a 24-hour period. Each unit is remotely programmed with values for the internal clock, energy budget and budget reset time. The Urja Bandu allows fixing the maximum total daily demand (in kWh) for micro-grids, providing stability to the system. | Solar off-grid micro-grids. | Several appliances. | Not available. | India, Australia (remote Aboriginal communities) |
| Devergy<br><br>http://www.devergy.comw | Energy meters enable a pay-per-use approach and remote monitoring of faults. | Off-grid solar micro –grid. | Several appliances: lights, TV, radio, refrigerators. | Installation cost of the micro-grid is largely covered by Devergy, except for a small connection fee. Prepayment of electricity by buying credit with scratch cards and sending an SMS obtaining a credit code to the Devergy payment system. Credit can be purchased for the same value of mobile phone credit, and the energy pricing is | Tanzania |

| Name of company/product | Real time monitoring technology | Generation technology | Energy services | Business model | Geographic scope |
|---|---|---|---|---|---|
| | | | | lower than for kerosene lighting or dry-cell batteries. | |
| DT Power/Mobisol/Plug in the World<br><br>http://www.pluginthew orld.com/mobisol/hom e.html<br><br>Germany | A Mobisol controller transmits real time information to Mobisol head office. Payments are made through mobile phone using the platform M-PESA. The remote monitoring technology transmits consumption and technical data. Potential maintenance problems are swiftly identified and the system can be locked automatically in case of overdue repayment. | SHS 20W, 60W, 120W and 200W. | Smallest system: light for 2 rooms and charging for 4 mobile phones.<br><br>Largest system: multiple lights, laptop, TV, refrigerator, 10 mobile phones charged simultaneously. Enough energy to run a business. | Pay-as-you-go through mobile banking and microfinance, with a 36-month instalment plan. | Kenya and Tanzania.<br><br>Created in 2010, there are currently 2 pilot projects with 300 units deployed. |
| Econet Solar<br><br>http://www.econetsola r.com<br><br>South Africa | A power control module links the home power station to the mobile phone network to allow mobile payments and blocking of the unit when the credit runs out. | SHS. | 4 lights and mobile charging. | Prepayment through mobile phones. | South Africa |
| e.quinox<br><br>http://www.e.quinox.or g/index.php/our-solutions/standalone<br><br>UK | Mobile-payment-based pay-as-you-go scheme. Solar panel connected to sealed box. Customers buy credit added to the box via an unlock code. The system is unlocked for as long as the credit lasts; when ‘unlock’ expires a new unlock code can be requested via mobile payment. | SHS. Two sizes: Home and Pro. | Home size provides lighting and charging small appliances.<br><br>Pro model enables small productive appliances. | Pay-as-you-go solar lighting through mobile phones. The payment scheme is rent-to-own, which encourages customers to keep paying on a regular basis and to take good care of their system. | Rwanda |

| Name of company/product | Real time monitoring technology | Generation technology | Energy services | Business model | Geographic scope |
|---|---|---|---|---|---|
| Gram Power<br><br>http://www.grampower.com<br><br>USA | Smart meters installed in shops, homes and telecom towers. The meters together form a remotely manageable communication network that eliminates power theft and payment defaults, optimises supply and demand of power, allows wireless payments and provides grid performance data to Gram Power. | Energy efficient smart micro-grids. Energy sources include solar, biomass, wind, conventional grid or a combination of sources. | On-demand, reliable electricity to telecom towers and rural households, to power fans, lights, TVs, mobile phones and other small appliances. | The micro-grid earns from prepaid purchases from households and businesses and from fixed monthly payments from telecom towers for a guaranteed power supply.<br><br>The local entrepreneur purchases bulk energy credit from Gram Power at a wholesale price by depositing money in the Bank. These energy credits, deposited in its Energy Wallet, which can be transferred to consumers' meters once they prepay for it. | India |
| Hessex<br><br>http://hessex.com<br><br>Australia | The meter is connected to the mobile network and monitors payments, blocking the system when credit runs out. | SHS | Lighting | Solar lighting systems can be purchased on a pay-as-you-use basis, using mobile phones. Once the sum of the repayments equals the total cost of the system, the solar lighting is free to use for the lifetime of the system. | Not available. |
| Lumeter Networks<br><br>http://www.lumeter.net/ | Off-grid electricity meter that allows prepayments through mobile phones. Cloud accounting software transmits data on payments and time of usage to renewable energy providers who are providing access to electricity for the poorest populations in | They only offer the meter, which can be integrated with any generation system (e.g. | The meter can be integrated with lights or batteries provided by other suppliers. | Prepayment system, with customers using their mobile phones to buy electricity credit. | Peru |

| Name of company/product | Real time monitoring technology | Generation technology | Energy services | Business model | Geographic scope |
|---|---|---|---|---|---|
| | developing countries. | solar, wind, hydro). | | | |
| Lumos<br><br>http://nova-lumos.com | No details provided on website. | SHS | Lighting, charging of cell phones and power for small appliances. | Pay-as-you-go model. | No details provided on website |
| MeshPower<br><br>http://www.meshpower.co.uk<br><br>UK | Entire system connected to an online management portal and monitored and controlled remotely. | Micro-grids powered by diverse sources, including solar, hydro or wind. | Peak power allowance of 60W per customer. Customers are provided with lights and USB chargers. | No details | Field trials expected for 2013 |
| M-KOPA<br><br>http://www.m-kopa.com<br><br>Kenya | A GSM communications module is attached to the product, to update credit purchased through mobile payments. | SHS | 3 bright lights and mobile charging. | Initial deposit followed by periodic payments on a pay as you go basis, for up to one year. After completing payments, customers own the product outright. | Kenya<br><br>More than 15,000 consumers |
| Off-Grid:Electric<br><br>http://offgrid-electric.com | Not detailed | Solar | Lighting | Prepayment | Not detailed |
| Powerhive<br><br>http://powerhive.com<br><br>USA | Cloud-based software platform that tracks and manages power generating assets, provides real-time data/ analytics as well as prepaid billing via existing mobile money services. The software platform features: a web-interface. | Micro-grids | | They provide their technology to local entrepreneurs that take the role of ESCOs, providing energy services to final customers. | No details yet; partner programme starting in 2013. |

| Name of company/product | Real time monitoring technology | Generation technology | Energy services | Business model | Geographic scope |
|---|---|---|---|---|---|
| | with advanced statistics, user profiles and usage analysis; automated prepayments through mobile money integration; load profile analysis and automated dynamic pricing and prioritization and rule-based remote control of solar assets and/or user access points. The hardware provides highly accurate metering and wireless communication. | | | | |
| SharedSolar<br><br>http://sharedsolar.org<br><br>USA | Software for a metering service and a gateway that allow pay-as-you-go metering, control and monitoring for rural micro-grids. Payments can be made via scratch cards or android applications. | Adaptable to any off-grid generation technology that supplies a micro-grid. | kWh | Off-grid ESCO with pay-as-you-go solution. | Mali: 9 systems (+8 planned); Uganda: 8; Haiti: 2 under construction. |
| SIMbaLink<br><br>http://simbalink.com/<br><br>USA | The SIMbaLink data monitoring system is a module with GSM connects to the charge controller in a SHS , logs data about the battery and sends it wirelessly to the solar company, that can lock or unlock the system according to credit availability. | SHS | Provided by solar companies, depend on the size of the system. | SimbaLink's customers are SHS providers who are enabled to sell their products on a pay-as-you-go basis. | East Africa: Uganda, Kenya, Tanzania |
| Simpa Networks<br><br>http://simpanetworks.com<br><br>India | Progressive purchase technology is a combination of product-embedded hardware plus cloud-based software that enables a series of small payments over time and the locking and unlocking of the system. | SHS | No details about the size of the solar system. | Small initial down payment and then prepayments for the energy service using a mobile phone and on a rent-to-buy basis, until the system is fully paid and unlocks permanently. | India |

| Name of company/product | Real time monitoring technology | Generation technology | Energy services | Business model | Geographic scope |
|---|---|---|---|---|---|
| Stima Systems<br><br>http://www.stimasystems.com<br><br>USA | Embedded control chip into portable solar charger that locks the system every week unless payment is received over a mobile phone. | SHS | Lights and chargers | Pay-per-use and group financing practices. To ensure collection, they require users to co-guarantee payments. User groups agree to co-guarantee full payment. If one person does not pay, no one is reactivated, forcing the group of users to self-enforce payments. | Kenya |
| Sonopro Power and light<br><br>http://sonopropower.com<br><br>USA | RTM of top-ups and transmission of enablement periods to a control chip embedded in the charger that blocks when the enablement period runs out. | SHS | Light | Small up-front payment and pay-as-you-go plan, consisting on prepaid enablement periods. Once the lamp has used enough enablement periods, it is unlocked forever. The system enables lamp-to-lamp transfers. | Not detailed |

# 5 Review of the evidence on the success of RTM technologies to improve access to electricity for the poor

Evidence of the effectiveness of RTM technologies in improving electricity access for the poor is very thin. We reviewed the academic literature available in ScienceDirect, which delivered only six relevant papers focusing on developing countries. Two looked at prepayment billing systems in on-grid systems and four dealt with off-grid systems.

The papers looking at prepayment billing for on-grid systems explore the cases of South Africa (Tewari and Shah 2003) and Rwanda (Mwaura 2012).

Eskom introduced a prepayment scheme in South Africa to deal with three main problems of traditional billing: (1) high day-to-day management costs of processing accounts and maintaining connections and disconnections; (2) lack of an appropriate infrastructure to allow post-consumption billing, as consumers did not have permanent jobs or bank accounts, fixed addresses or postal services in their neighbourhoods and many were illiterate and did not understand the bills; and (3) many consumers did not have a budget and resented the idea of paying for fixed costs when they did not use the service. The prepayment scheme in South Africa is considered a success as it allowed connecting many small and dispersed consumers of electricity in a very short span of time (3–5 years). It has empowered small and dispersed consumers who would not have been reached by traditional billing systems and improved their understanding of how to control energy expenses. It has also brought significant advantages for Eskom: improving customer service, the cash flow of the business and the safety of their employees, who do not need to access customers' property, reducing the risk of underpayment, electricity pilferage and administrative and maintenance costs. The success is attributed to careful planning, a good marketing campaign to create awareness of the benefits of prepayment among consumers and differentiated tariffs adapted to the large variation in payment abilities of small and dispersed consumers. The most basic tariff for low-usage residential customers was targeted at low-income consumers that need only home light.

The public electricity utility of Uganda, Electrogaz, started to roll out a prepayment billing system in 1995 after it became difficult to bill and collect revenue from consumers after the 1994 genocide. Since then, the ratio of customers on prepayment scheme has grown steadily from 30 per cent in 1998 to above 80 per cent in 2008. Prepayment contributed to a reduction in non-technical energy losses from 40 per cent in 1998 to 2 per cent in 2008 and to a reduction in operational costs of the electric utility. The roll-out of the prepayment system required significant financial support coming mainly from development partners.

Problems of pilferage and excess usage are not relevant to off-grid systems such as SHS or where customers purchase systems for their own use, or micro-grids with a small number of consumers where fraud can be more easily tracked. In these instances, fee-for-service or prepayment schemes are used instead mostly to reduce upfront payment for the systems, which is considered one of the most important barriers to improved access. Four papers have been identified dealing with the use of these schemes in off-grid systems. All of them deal with SHS, in Zambia (Lemaire 2009), South Africa (Lemaire 2011), Fiji (Dornan 2011) and several countries (Pode 2013). The experiences of all these countries show the following common success factors:

- Public support through capital subsidies that can cover most of the initial costs of solar systems. In fee-for-service schemes, the service provider remains the owner of the system until the customer has been able to cover its full cost through regular instalments. Therefore finance availability is key to the sustainability of the scheme. All the schemes analysed by the papers reviewed relied on public funds to cover initial capital costs. Customer fees should then be able to cover operation and maintenance costs of the SHS by the service provider.

- Robust SHS units and a strong after-sales service network that can keep the systems functioning through effective repairs are essential for the continuity of the scheme. A good maintenance service requires frequent visits to customers to check the performance of their systems. This can be very costly for remote and sparsely populated communities. RTM technologies can include diagnosis modules that inform the service provider about the performance of the systems in real time, hence avoiding the need to have technicians in the field at all times. Good training of technicians and customers are needed to be in place to ensure good system performance.

- The right incentives in place for the service providers who should be paid for energy service provided, not for installation or performance checks of systems.

- Prioritisation of densely populated and relatively wealthy communities to minimise maintenance costs and the risk of non payment. This still excludes the poorest from obtaining access to electricity.

- Affordable customer fees that take into account the different abilities to pay, while ensuring the financial sustainability of service providers. Affordability has three dimensions: total cost, upfront price and payment flexibility.

# 6 Conclusions and discussion

Despite the large potential of RTM technologies for the provision of pro-poor electricity, and the large and growing number of suppliers, only anecdotal information exists about the financial sustainability of the business models that they enable and their success in removing financial barriers to access of electricity. Although several publications exist detailing the case of SHS, evidence is particularly thin on the use of RTM technologies beyond SHS.

Information gathered through a review of relevant literature and interviews with suppliers show the following preliminary conclusions about the contribution of RTM technologies for the provision of access to electricity for the poor:

- Even though a higher share of the population is reached by pay-as-you-go business models enabled by RTM technologies than by traditional upfront payment models, the poorest strata of society are still left behind. Energy service providers prioritise relatively wealthy and densely populated communities in their deployment strategies to achieve financial sustainability. Further research is required to determine the actual impact of these new business models on enhancing access to electricity for the poor. Without robust impact evaluations it is not possible to draw conclusions on the effectiveness of pay-as-you-go schemes to reach the poor. Subsidy-driven programmes specifically targeted to the poorest population may need to be in place to ensure universal access to electricity.

- Access to electricity depends on affordability for the poor. Affordability includes upfront payments, fees for use and payment flexibility. RTM technologies have tackled all of these components to render electricity more affordable for the poor. However, energy service providers usually face financial fragility, having to cope with inflation, currency exchange volatility, customers unable to cope with increased fees, and high repair and maintenance costs. RTM technologies can contribute to reducing maintenance costs through diagnostics modules that substantially reduce the need for technicians in the field and through awareness messages to customers through mobile phones, which allow better use of the system and a faster response time to changes in tariffs. Further research is required on how to determine customer fees that balance affordability with financial sustainability.

- Finance for initial capital costs is one of the main challenges for fee-for-service business models where the energy service providers provide credit to their customers by remaining owners of the systems until full costs are covered through several instalments. All the suppliers identified through our inventory are small, young and with low capitalisation. They face the so called ‘valley of death’, or gap in financing between the grant funding for a proof of concept and commercialisation. The academic literature reviewed shows that this finance can come through public–private partnerships where the public sector covers initial costs and private companies collect consumer fees to cover operational costs. A recent article in Forbes quoted by GSMA (2013) suggests that results-based financing could be used by multilateral banks and donors to drive the growth of the sector without distorting the market. Results-based financing is based on five main principles: fund services, not capacity (e.g. lumens of light, hours of radio, number of phones charged); fund durable systems by reserving some funding to be provided only after systems are demonstrated to keep up good performance after 1–3 years; only fund on auditable data such as location of customers, energy consumption, duration of the system etc.; release funding quickly and transparently; and build a broad market by not providing more than 20 per cent of available funds to a single company, country or organisation. RTM technologies can support a results-based financing model by providing auditable data on energy services provided, performance and durability of the system.

- Technical failure and poor maintenance of the systems is seen as one of the main problems of SHS deployed in rural communities. Availability of well-trained local technicians, training of consumers to avoid systems failures, and diagnostics modules capable of transmitting real time performance data can contribute to improving system durability.

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