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An assessment of South African prepaid electricity experiment, lessons learned, and their policy implications for developing countries

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Abstract

This study reviews the economics, logistics, and technology underlying the South African experiment of prepaid electricity. Although this experiment has resulted into benefiting large masses of small and dispersed consumers, it has also generated a set of new problems that could not be visualized at the inception of the experiment. The success of this program can be largely attributed to a number of factors, including a good marketing campaign, innovative tariff schedules, better planning and management, and so on. Lessons learned from this experiment are useful for policy-making purposes in other developing countries of Africa and Asia.

Keywords: Prepaid electricity; Policy; Technology; Tariff; Cost

1. Introduction and objectives

The usual way to pay for electricity is that it is metered and billed to the electricity consumer. The costs of metering, billing, and collecting dues becomes huge when electricity is to be supplied to large numbers of tiny and dispersed consumers. High electricity costs to consumers provides them with incentive to pilfer electricity or to fudge meter readings. In some countries, for example in India, it is alleged that a large part of (30–35%) transmission and distribution loss is due to pilferage alone. To counter this problem, many State Electricity Boards (SEBs) in India switched from metered to flat tariff regime in the 1970s. However, this rendered the SEBs hopelessly less viable. The re-introduction of metering has invited much opposition, with host of other problems related to it. One solution to it is to go for prepaid electricity. In this context, the South African experiment with promoting the use of prepaid electricity cards by Eskom (organization responsible for producing and distributing electricity in South Africa) is notable and may offer solutions to many developing countries which face similar problems like India. The South African experiment is now roughly 12 years old and its assessment can provide useful insights to policy makers in the power sector in many developing countries of Asia and Africa.

The major objective of this study is to understand the economics, logistics, and technology underlying the South African Experiment of prepaid electricity card system. The study makes an assessment of the experiment in resolving the problems of viable power supply to small, dispersed consumers and discusses its relevance for the developing countires. More specifically, the study is aimed at answering the following questions in particular:

(1) What factors motivated Eskom's experiment with prepaid electricity card system?
(2) How does the technology work in the field condition?
(3) What is the economics of the prepaid electricity and what are other possible advantages and disadvantages of the prepaid electricity?
(4) How good or poor has been the acceptance of the technology and whether it has done well in particular market segments and not in others? If so, why?
(5) What has been the consumer's assessment in different market segments and how do they view this technology?
(6) What has been the Eskom's assessment of the impact so far and has it been beneficial to both Eskom and Consumers?

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(7) Is there any indication of a stoppage of the pilferage of power, expanding the reach of electricity to far-flung areas, reducing the metering and collection cost, among others?
(8) Has there been a need for an aggressive marketing of prepaid electricity, initially through subsidies to get consumers to switch to it?
(9) What lessons from the South African experience should be kept in mind while planning such introduction of technology in the developing countries?
(10) What might be the prospects, problems and advantages of introducing prepaid electricity technology in power distribution in the developing countries?

The motivation for prepaid electricity system and a brief history of development of prepayment system in South Africa, are discussed in Section 2 (objective 1). The principles and functions of prepayment technology are detailed in Section 3 (objective 2). The economics of prepaid electricity and other cost-related considerations are discussed in Section 4; followed by the various advantages and disadvantages to Eskom and to consumers in section 5 (objective 3). Factors affecting the success of and impediment to the expansion of prepaid electricity are assessed in section 6 (objectives 4–8). The lessons learned from this experiment are summarized in section 7 (objective 9). Conclusions and prospects for promoting prepaid electricity in developing countries are discussed in section 8 (objective 10).

2. Eskom's prepaid electricity experiment[1]

Prior to 1988 Eskom supplied electricity mainly to large customers like mines and municipalities. At that time, although Eskom was one of the largest electricity generators in the world, it only had 120,000 customers and all of them were on billed accounts. In 1988, Eskom had a change of strategy, that is, to supply electricity directly to the large masses of domestic customers who did not have access to electricity at that time. Most of these customers were in rural areas. Then came the revolutionary change: ‘‘Electricity for All.’’ The vision of Eskom was broadened and positioned in the context of African Renaissance. Its major objective was redefined as to vigorously promote economic growth in Southern Africa and, at the same time, support social and economic objectives in energy and selected markets.

This visionary change in 1988 brought several problems to the forefront, which can be basically divided into three categories. (1) many small areas had to be supported with the smallest amount of Eskom personnel. The standard billed accounts system required too much day-to-day management to process accounts and to maintain connections and disconnections. This means that the Eskom had to operate with a low level of management and maintenance. (2) many of the areas, where potential customers lived, had no infrastructure and economy was merely subsistence one. People did not have permanent jobs or bank accounts. There were no fixed addresses to which billed accounts could be posted. Furthermore, there were no postal services in these areas. But, all these are required for a billing to operate effectively. Many customers were illiterate and did not understand the bills that arrived only after the electricity has been consumed. Many did not have budget to pay for the fixed charges—a component of the billed account. (3) even many resented at the idea of paying a fixed charge—an expense that they believed they did not incur. To address these and other related problems, Eskom initiated the development of the basic prepaid system, which is still in use and has been growing over the years.

2.1. A brief review of development of prepayment system

The first inquiry for electricity dispensers (EDs) or prepayment meters in Eskom was issued in 1989. This inquiry was based on short specification produced by Eskom. Contracts were issued to two manufacturers (AEG (then Schlumberger) and Conlog) based on this specification for 10,000 meters. An earth leakage protection device was included with the meter and dispensers were only required to perform Amp-hour measurement instead of KWh (KiloWatt hours).

The specification document was upgraded and made more comprehensive in 1990 (it included NRS009, Part 1, 2, and 3). This time the earth leakage protection device was removed from the ED. The specification based on NRS009 were contracted out to three manufacturers (AEG, Conlog, and EML (then Spescom); some 30,000 m were ordered, 10,000 m per manufacturer. The project was renamed to the ‘‘Eskom Electrification Project’’. Lightning related failures were also becoming apparent during this time. An exhaustive investigation established that the international requirements as specified in NRS009 document were not stringent enough for the South African conditions. A lightning arrestor was developed in conjunction with the Council of Scientific and Industrial Research (CSIR) and was installed in the EDs; this effectively addressed the lightning problems.

In 1990, The South African Bureau of Standards (SABs) provided a completely new specification of prepayment meters and replaced the old one. However, it did take into account the NRS009 while creating the

[1] A large part of the information gathered for this study was collected by personal communication with Jimmy O'Kennedy and from a website created by him (O'Kennedy, 2001).

new specification. And, the total numbers of prepayment meters to be manufactured was increased to 200,000 per annum in 1993. It was further planned to be increased to 300,000 meters per annum by the year 2000.

Having standardized the specification of prepayment meters by the SAB, Eskom identified the need for standardizing the vending system to be able to sell electricity from 1 meter to other, which were manufactured by different manufacturers. Eskom initiated a program to standardize the EDs and the vending process in 1993. An inquiry was issued for the vending system based on a draft specification and for EDs to accompany it. Later, the development of the new common vending system (CVS) was started jointly by Eskom in conjunction with Conlog–a meter manufacturing company.

The development of CVS was followed by the development of "Standard Transfer Specification" (STS). Both Conlog (a meter manufacturing company) and Eskom developed the STS. The STS was developed to enable the new vending system to transfer credit to all types of meters; this warranted developing a standard transfer medium and protocol to the meters. All EDs produced from the beginning of 1994 implemented the STS and allowed the CVS to produce tokens for any manufacturer's EDs. The first functional specification (MC 171 rev 2.10) was released at the same time and has been implemented in all the STS based EDs since 1994. In 1994, the modified specification for lightning arrestors (TRMSCAAP2 rev 2) that could withstand 400 V was also released.

In 1996, to achieve a further reduction in the cost of electrification, a 2.5 A Circuit Breaker Unit (CBU) was designed (MC 196 rev 1.01); a CBU is a device equipped with earth leakage and overload protection, designed to supply up to 2.5 A and to be managed on a flat rate tariff. Operational cost studies were done in late 1997 and Eskom came to the conclusion that prepayment is still cost effective or cheaper than the CBU flat rate system. The decision was then made to implement a prepayment 2.5 A prepayment system with ECUs instead CBU.

The CVS and STS meters formed the basis of the existing prepayment system of Eskom. The CVS and STS have been further improved and are adopted as standard by other electricity utilities, such as Durban Metro, in South Africa. South Africa is now seen as world leader in prepayment technology and many other countries have adopted the South African Standards.

3. The prepayment technology

How prepayment technology works is explored briefly in this section. The technology is rather simple but it requires an understanding of functioning of various components that produce the final delivery of service. The basic principles of the prepayment system are discussed first, followed by the description of the functioning of the prepayment technology. Two important technologies—STS and CVS—which are very essential for functioning of prepayment technology, are also discussed in this section.

3.1. Principles of operation of prepayment

Two important elements of operation of prepayment system are token technology and systems approach to management (Bezuidenhoudt, 2000a, b). The prepayment meters or EDs are installed at the customer's residence or any other point of sale of electricity. A prepayment meter is designed to supply up to 60 A current of electricity. EDs plug into a standard passive base or socket and the output is connected to a distribution board. The customer then has to buy tokens from Eskom. These tokens are then inserted into the EDs. If token is valid, the ED accepts the token and adds the credit (amount of units of electricity encrypted on the token, kWh) to the current credit in the ED. The customer then can use electricity until the entire credit is exhausted and at that point of time the ED interrupts the electric supply. A token can only be entered once and is issued for use in a unique ED, that is, customer buys a token for his/her specific ED. However, token can be entered at any time to prevent interruption.

Eskom uses two types of token technologies for EDs. Both types are of a use-once-and-dispose nature. The customers cannot reuse the tokens and once entered into the ED the credits are recorded in. Two types of tokens are used: (1) disposable paper cards with a magnetic stripe (conforming to 1S0780 and 7811 size and strip location), and (2) numeric token which is a strip of paper with a 16 or 20 digit number which is entered into the ED, via a keypad on the face of ED, by the customer.

The choice of token depends upon the types of meters—magnetic card and numeric keypad. The magnetic card meters accept the magnetic token while the numeric tokens are acceptable to numeric or keypad meters. The numeric token is unique to South African EDs in that it need not be transported physically and thus making them ideal for sale over the telephone. Tokens for prepayment can be categorized as being "one-way" or "two-way". The one-way tokens transfer credit and control information from the sale point to the meter; the tokens are usually discarded after use. The major drawback with one-way tokens is that the Eskom cannot determine how much electricity has been disbursed through the prepayment Electrical Dispensers. The Eskom personnel have to visit the customer's premises to determine the true consumption. The two-way tokens require that customer to return the token to

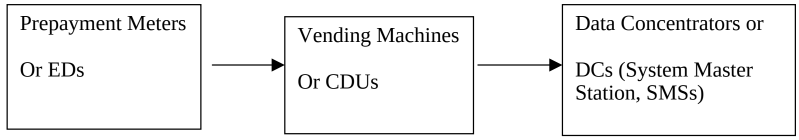

Fig. 1. Basic components of the prepayment system: a schematic diagram.

the point of sale for the next purchase. This allows the Eskom personnel reading the data stored by the meter from the returned token. The statistical processing is done by the data management system.

In the case of the conventional meter (rotating disk Ferraris meters), the functions of technical support, maintenance and revenue collection and management can be to a large extent be operated autonomously. In contrast, the prepayment metering requires an integrated system approach. It requires (1) an effective and available token (electricity) sales points, and (2) proper sales management systems (which is made up of both manual person based as well as information technology equipment based). For example, producing bills out two days later does not deprive customers of electricity, whereas inoperative prepayment sales point for two days will cause significant customer inconvenience. It is therefore emphasized that when prepayment electricity is to be introduced, we must give consideration to the whole system in its entirety, not just to the prepayment meters alone.

3.2. Functioning of prepayment technology

As discussed above, the prepayment electricity is based on systems approach and its revenue and maintenance management is inextricably linked with the operation of entire system. Eskom started the development of basic prepayment system in 1993. This system consisted of the following components: (1) Prepayment meters or also called EDs; (2) Vending machines where the customers can purchase electricity credit, known as Credit Dispensing Units (CDUs); (3) Data Concentrators (DCs) that manage the CDUs and collect the transaction data from the CDUs; this is also called the System Master Station SMSs (Fig. 1).

The EDs can be of two types: proprietary meter and STS meter. Proprietary meters are the old meters which were supplied to Eskom by companies like AEG, Ash, Conlog, Plessey, and Spescom. The STS meters are the new meters specified by the Eskom, which accept tokens conforming the STS specification. Originally the EDs were not built with protection devices to arrest lightning; later these changes were made and such an ED is called Electricity Control Unit (ECU).[2]

The CDUs are nothing but a prepaid token vending machine; these are of two types, proprietary and common vending. The proprietary CDU vends only proprietary tokens; on the other hand, the common vending system CDU vends both STS and proprietary tokens. Typically a vending machine is currently installed for every 800–1000 customers.[3] The DCs or data concentrators collect information from CDUs and transfer it to mainframe computer.

In order to manage the prepaid electricity, the Eskom has divided the entire geographical area of electricity supply into *Supply Group Codes* (SGCs). Eskom buys meters from suppliers pre-coded for a specific SGC or on a default SGC and then codes the meter for the specific SGC. This personalizes a meter for a specific area and also adds a few additional items like specific tariff index, etc. All this information is combined to form a key for the meter and every token is encrypted under such a key. If the key is wrong, the meter will not accept the token. The whole encryption process is defined by the STS standard. Every meter is also shipped with a meter card with this same information. The only use of the card is to make it easy to identify the customer, otherwise the entire information will have to be typed in to the vending machine (CDU) when customer buys electricity, but now the customer can just swipe the card to identify his meter details.

The vending machine or CDUs, which is nothing but a PC that is close to customers, stores the hidden SGC keys. This helps the machine to identify the exact location of the customer. A customer who wants to buy electricity presents his meter card to vendor, pays the sum of money that he/she wants to spend. The vending machine then produces a magnetic or keypad token for the customer. The customer can take it home and enter into his meter. The transaction data is then uploaded from the vending machine to the SMS and mainframe computer for statistical and data management purposes.

Each meter card contains the following information: (1) supply group code, (2) key revision number, (3) tariff index, (4) meter number. The moment the customer swipes his/her meter card in the vending machine or CDUs, it reads the information and then generates a meter key taking into account the: (1) key revision number, (2) associated vending key (which is invisible), and (3) tariff index (Fig. 2). This meter key is also stored

[2] An ECU is a prepayment meter designed to supply up to 20 A current. An ECU is an ED with earth leakage and over-current protection built-in.

[3] For some 3 million prepaid customers in South Africa, a minimum of 3000–4000 vending machines are installed.

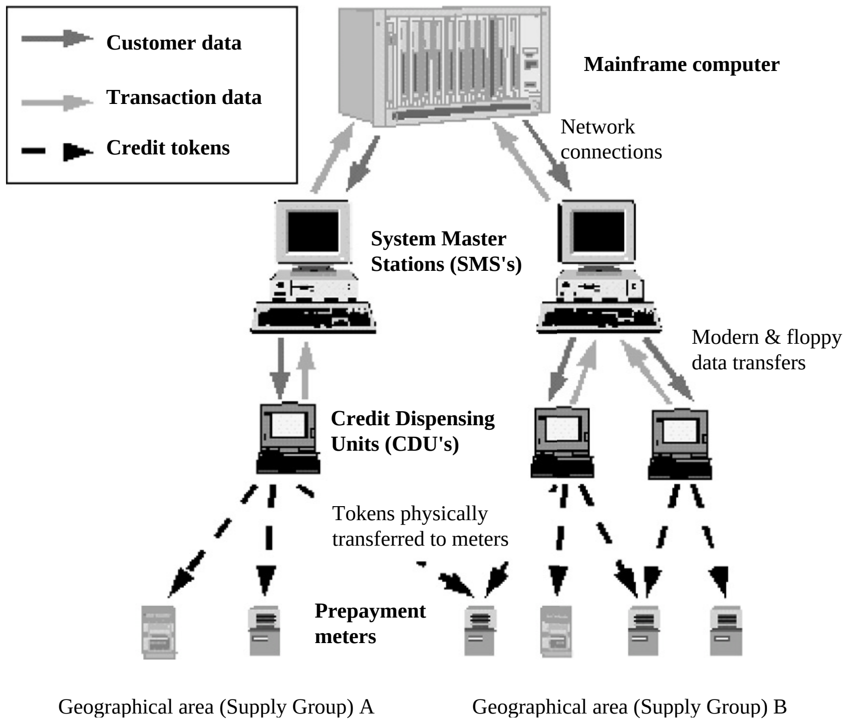

Fig. 2. A schematic diagram showing functioning of Eskom prepayment system (source: http://www.eskom.za/electrification).

inside the ED. Thus, meter keys—one in CDU and other in ED—can exchange tokens. Once a customer pays money and gives his/her meter card to the vendor, the vending machine generates a token, keeping into account meter key and tariff rate. The credit token is thus generated and fed to the ED (Fig. 2).

3.3. The development of CVS and STS

The development of the CVS and the STS are the two pillars of prepayment technology and need to be understood well. The CVS consists of various groups of CDUs that are distributed at various points of sale (POS) locations, with each CDU group concentrated by a System Master Station (STS). The SMSs are in turn concentrated by a Transaction Manager (TM) on Eskom's Mainframe Information System (MIS), as depicted in Fig. 3.

In other words, CVS incorporates the network of CDUs, SMSs, and the TM, all interfacing to the MIS. The MIS consists of several subsystems which include: (1) Customer Information System Data Base (CIS DB); (2) Customer Management System (CMS); (3) General Ledger (GL); (4) Nedisys-ED Tracking Ssytem (NED); (5) Power Billing System (IPS). In brief, the CVS provides for the vending of a STS token, which enables the individual customer to use electricity. This enables CDUs to vend STS tokens, which are compatible to EDs that support the standard transfer algorithm (STA). The CDU also has the capability to interface to standard token translator (STT) to support a proprietary token, using a proprietary algorithm. This ensures the backward compatibility for proprietary EDs that are already installed.

The implementation task of CDU and ED becomes easier if the STS is understood well. During the early years of prepayment electrification, the focus of specification and standardization was on the ED, not on the vending system and other infrastructure. This produced a variety of vending systems which were usually incompatible with each other. This incompatibility led to the inability of vending system of one manufacturer to vend to the ED of another. As a result, a distributor has to purchase different vending systems to support the sale of prepayment electricity. This proved expensive and operationally inconvenient. To overcome this problem, Eskom, being a major buyer of EDs, initiated the process of standardization so that prepayment token from a CDU, developed by one manufacturer, Eskom being a major buyer of EDs initiated the standardization so that prepayment tokens produced from a CDU developed buy one manufacturer could be used into an ED developed by another manufacturer. This required development of standards, which could ensure compatibility. It should be noted that the STS is a standard for the electricity dispensing industry, whereas the CVS is a system implemented according to a set of standards which is STS.

The STS is thus a standard for the electricity dispensing industry, which allows STS compatible

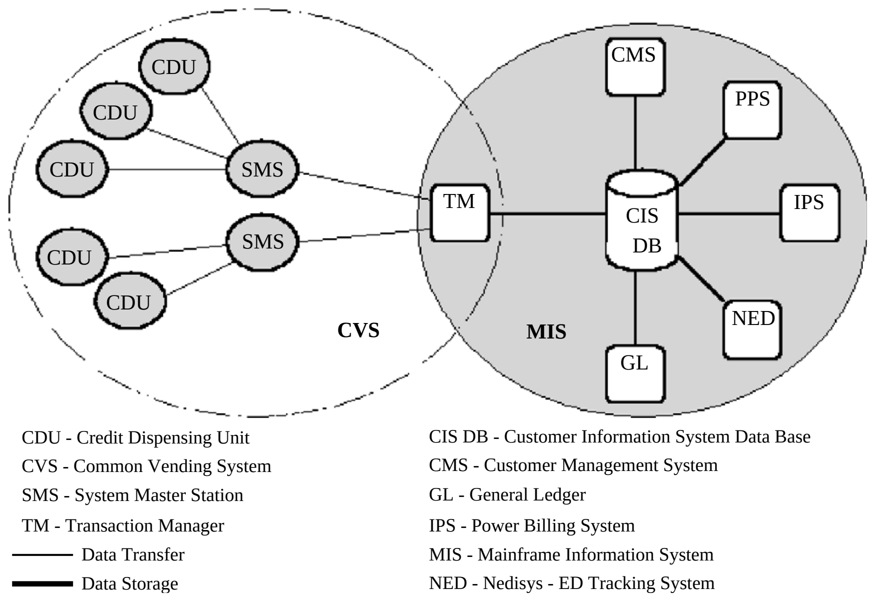

Fig. 3. A schematic overview of CVS (source: http://www.eskom.za/electrification).

dispensing and vending equipment from different manufactures to operate with one another. This benefits consumer, distributor and agent, thereby promoting competition, cost-efficiency, and convenience in the industry. The STS is based upon a number of concepts; most of these concepts are directly addressed in the STS, but some being the subject of other specifications/standards applicable to other areas such as the CVS, are addressed elsewhere as well. To ensure compatibility, the STS defines the following: (1) A set of management and credit functions to be supported by an ED. (2) The various data elements required by the CDU to support the implementation of these management and credit function. (3) The format of management and credit token data corresponding to the management and credit functions. (4) The cryptographic methods of encrypting and decrypting the formatted token data so as to ensure its authenticity and/or secrecy during transfer between CDU and ED. (5) The cryptographic method of key management in support of the encryption and decryption of token data. (6) The type of token technology that can be input by EDs and output by CDUs; and (7) The method of encoding token data for each type of token technology.

4. Economics of prepaid electricity

The cost of electricity can affect the price that is to be charged to the electricity consumers. The price to the final consumer is thus made of several types of costs. Eskom's cost of electric supply can be explained by way of the supply chain. This includes five types of costs: (1) generation, (2) transmission, (3) distribution, (4) reticulation, and (5) service. Generation involves the cost of raw material and other input used in the production of electricity in power station. Eskom has some 25 power stations which generate approximately 97% of South African electricity supply. From the power station electricity is sent to all parts of the country. The transmission network carries a very high voltage current and only very large customers can be supplied directly from the transmission network. Only 2% customers are directly sold electricity from the transmission network. The electricity is then further distributed through the distribution network. The electrical power is transformed to a lower voltage at distribution substations. Some larger customers such as towns or factories that are supplied directly from the distribution network. From the distribution network the electricity is then distributed to the customer's property by means of reticulation network, generally located in the immediate area at a lower voltage. Most of Eskom's customers are supplied from reticulation network. At the end of supply chain is the customer's service connection. This includes any lines or cable or metering to connect the customer's installation to Eskom's network. It can therefore be concluded that cost of electricity to customers depends upon where one is in the supply chain. The higher up the supply chain, the fewer networks Eskom has to build to supply a customer (Fig. 4).

Various types of costs that Eskom incurs can be classified into three categories: (1) fixed costs which primarily covers the materials and erection cost of establishing all of Eskom's equipment; this is generally referred as to the capital cost, (2) operation, maintenance, and administration costs which refer to the

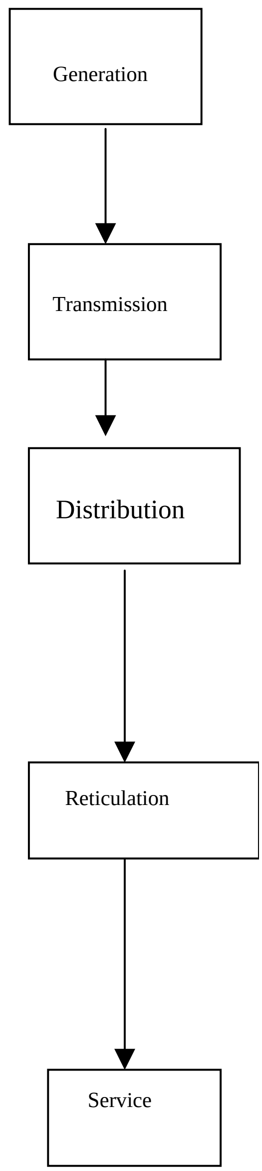

Fig. 4. A general overview of costing of electricity in South Africa.

costs incurred in ensuring that electricity supply is maintained, and (3) raw material or variable cost which includes cost of coal or water. In general, the pricing of electricity by Eskom must cover all of the above costs so as to remain economically viable enterprise in the economy. The price set by Eskom is designed as far as possible to meet the following objectives: (1) Pricing must provide the means to recover adequate revenue. (2) It should promote overall economic efficiency. (3) The price charged should be fair, equitable, and transparent to all customers and (4) Cost-effective tariffs should be established.

The price of electricity is implemented through a tariff package. A tariff package is made up of a tariff and various other charges and conditions applicable to electricity use. Different tariff packages are designed and made available to customers with different conditions and needs. For example, specific packages for residential sector, both rural and urban customers, are used by Eskom. In addition to tariff, Eskom also levies various charges depending upon individual circumstances such as connection fee, conversion fee, capital charges, service charges, and so on. For example, a connection fee is payable by the customer towards the cost of new connection. A conversion fee is payable when a customer converts supply or is applied when there are changes such as meter changes, changes in installation or when a supply point is shifted.

The network capital costs are not recovered through tariff but through additional capital charges over and above tariff. Generally speaking, the capital charges are of fixed nature and paid on monthly basis as a *monthly rental*. This is paid irrespective of usage of electricity. It is a contribution towards Eskom's fixed costs and escalates annually with Eskom's price increases. Sometimes this is also known as *basic charge*. A part of the capital charges is repaid towards the long-term use of capital. In Eskom, this is a non-escalating monthly capital repayment rate. It is a percentage per month of the total capital cost which need to be repaid. In 2000, this was set 15.5% annual discount rate and a repayment period of 25 years or less. The capital rate can change from 1 year to the other. In addition to charges, Eskom also levies service charges such as transfer fee (payable by a new customer when ownership of a conventionally metered point of supply changes hands), call out fee (payable when Eskom is called out due to a supply interruption and fault is found to be within the customer's installation), special meter reading fee (payable when a special meter reading is done at the customer's request), meter test fee (payable when a meter test is requested by the customer) and so on.

In brief, the two types of charges make up the tariff: (1) basic charge, (2) energy charge. The basic charge is a fixed charge payable every month, irrespective of electric usage and contributes towards fixed cost of supplying electricity. The energy charge covers the cost of electricity and is levied per kilowatt-hour of energy consumed; for example, 16.98 c/kWh. This is also called "rate" in colloquial language. The price equation can thus be written as follows:

$$P = \alpha + \beta Q,$$

where, P is the total price of electricity, α the basic charge, β the rate or energy charge rate and Q the amount of electricity consumed.

Eskom has a number of tariffs available to consumers. These tariffs are usually set according to the size of the supply, the type of supply, and whether the supply is urban or rural.

Table 1
Basic energy charges for different types of prepaid electricity usage, South Africa

Tariff	Electricity supply size	Basic charge	Energy charge
Business rate 1	Less than 25 kV A	R120.80 + VATt = R137.71	19.34 C + Vat = 22.05 C/KWh
Business rate 2	Between 25 and 50 kV A	R151.75 + VAT = R173.00	19.34 C + Vat = 22.05 C/KWh
Business rate 3	Between 50 and 100 kV A	R209.78 + VAT = R239.15	19.34 C + Vat = 22.05 C/KWh
Business rate 4	Less than 25 kV A	N/A	43.50 C + Vat = 49.59 C/KWh
Land rate 1	16 kV A–80 A (1 phase) 32 kV A–80 A (2 phase) 25 kV A–40 A (3 phase)	R226.13 + VAT = R257.79	First 500 k Wh @38.12 C/kWh 34 C (incl.VAT) > 500 kWh @ 22.05 C/kWh (incl. VAT)
Land rate 2	64 kV A–160 A (2 phase) 50 kV A–80 A (3 phase)	R257.05 + VAT = R293.04	First 500 kWh @38.12 C/kWh 34 C (incl.VAT) > 500 kWh @ 22.05 C/kWh (incl VAT)
Land rate 3	96 kV A–225 A (2 phase) 100 kV A–160 A (3 phase)	R315.07 + VAT = R359.18	First 500 kWh @38.12 C/kWh 34 C (incl VAT) > 500 kWh @ 22.05 C/kWh
Land rate 4	16 kV A–80 A (1 phase)	R85.13 + VAT = R 97.05	33.43 C + Vat = 38.12 C/kWh
Home power		R 41.53 + Vat = 47.34	22.58 C + Vat = 25.74 C/kWh
Homelight 1	(2.5 and 20 A)	N/A	33.12 C + Vat = 37.76 C/kWh
Homelight 1	(60 A)	N/A	37.25 C + Vat = 42.47 C/kWh
Homelight 2 (20 A)	(60 A)	N/A	28.76 C + Vat = 32.79 C/kWh
Homelight 2	(60 A)	N/A	32.89 C + Vat = 37.49 C/kWh

4.1. Costs of prepaid electricity

Eskom tariffs are linked to all types of meters installed. Irrespective of tariff, a consumer can choose to go for prepayment or conventional meter. Eskom follows three basic principles in this regard. Firstly, Eskom does not encourage prepayment meters in an area where vending sites are not situated close to the location of customer demanding prepayment meters. Even the conventional meters are not installed in the no-go areas which are very remote and costs to Eskom is very high. Secondly, current prepayment meters cannot handle a supply size of no more than 65 kV A.[4] Thirdly, prepayment vending system cannot handle fixed/basic charges and variable energy (high block vs. low block) rates. The fixed or basic charge has to be paid by normal billing system.

In general, prepayment meters are available for homelight, homepower, business-rate, and land-rate. The standard supply size available for prepayment supplies are:

- Single-phase: 16 kVA (2.5, 20, 60 A)
- Two-phase: 32 kV A or 64 k VA
- Three- phase: 25 kV A or 50 k VA (60 A or more).

Eskom requires a deposit prior to connection of prepayment meters. Generally the deposit is equivalent to the three consecutive months electricity bill which is estimated by the authorities. However, deposits are not required if prepayment meter is for homelight supplies.

[4] A charge per unit of kWh is called active energy charge. This may be fixed rate or vary with the amount of electricity used, e.g., block rate tariffs (different rates for peak, off-peak period usage).

Monthly rentals or basic charges towards repayments of capital expenditures are required to be paid by all prepayment-meter-owners; with the exception of the home- light and business rate 4 (Table 1). It is important to note that the prepayment meters cannot accommodate a tariff with both basic charge and energy rate, hence a monthly account is received by the consumer for the basic charge/monthly rental towards repayment of net work cost. Eskom supplies various levels of current under single, two, and three phase. Currently it providers four types of electricity supplies.

Single phase 2.5 A and 20 A supply: This is provided for customers with minimum electricity requirements and comprises electricity control unit (ECU) and double electricity plug outlet. This supply is only intended for very low usage customers that normally have only lights, radio, and television. It is not sufficient for cooking purposes. The meter charge depends upon the size of current. For 2.5 A supply, Eskom provides a free meter. However, this is done only in pilot projects area. This is the most commonly used electricity supply. It consists of an ECU and a double plug outlet but with a current limit of 20 A. It is intended to supply for lights, radio, television, basic cooking, refrigeration and ironing needs of domestic customers. Customers are required to pay an upgrade or installation fee to receive 20 A supply. For 20 A supply (both prepayment or conventional meters) the meter fee is R150.

Two phase 60 A supply: The 60 A supply is provided with an Electricity Dispenser (ED) and the consumer is required to provide his own internal wiring or distribution. The customer has to pay the full installation cost. This supply is typically used for consumers with hot water heaters or other small business. For 60 A supply, the meter (prepayment or conventional) charge is

R1000; this is the minimum cash amounts payable and additional charges based on actual costs may be raised as per current policy.

Three phase 60 A or more supply: This is provided with three phase ED and intended for business that require large supplies and are situated in areas that have prepaid electricity. This is not a frequently used electricity as businesses are generally supplied with billing meters on a non-prepayment account. Eskom has set different tariff rates for different categories of uses. At present, there are four categories of consumers: (1) low usage residential consumers, (2) medium-to-high usage residential consumers; (3) small business in urban areas; and (4) farmers and rural businesses. The details of current size and tariff stricture are given in Table 1.

4.1.1. Tariff for low usage residential customers (homelight)

For low usage residential customers, Eskom supplies the single phase (2.5, 20, 60 A current) electricity. Most of these consumers are from low income and need only homelight. The electricity meter is supplied free, although normally a deposit equivalent to three consecutive months' electricity bill is payable. For 2.5 A current supply, Eskom has offered prepayment meters without any charge but R150 and R1000 are levied towards meter charge for 20 and 60 A current supply. There are no basic charges to the consumers and a single energy charge is levied, depending upon the category of light (homelight 1 and 2) as shown in Table 1.

4.1.2. Tariff for medium to high-usage residential customers (homepower)

This is called homepower supply. It is suitable for medium-to-high usage residential customers, churches, schools, etc. Eskom requires a deposit equivalent to three consecutive months's electricity bills. The connection fees are levied and vary with the type of current subscribed. For single phase supply, the meter charge (conventional or prepayment) is R1000. For three phase supply, the charge for prepayment meter is R2500 and for conventional meter is R2100. These are minimum costs amounts payable and additional charges based on actual costs may be raised as per Eskom's policy. This category of customers are required to pay a monthly charge of R47.34 per month for each point of delivery whether electricity is consumed or not. A single energy charge is of 25.74 C/kWh is charged (Table 1).

The breakeven point for homelight1 (60 A) and homepower is 283 kWh/month, respectively. If electricity consumption is less than 283 kWh/month, then Homelight1 (60 A) is cheaper than Homepower. If more than 283 kWh/month is used, then Homepower is cheaper than Homelight.

4.1.3. Tariff for small businesses in urban areas (business rate)

This is intended for small businesses in urban areas. A supply of greater than 100 kVA is not permitted. The four business rates are available. Normally a deposit equivalent to three consecutive months' electricity bill is required. The connection fees or meter charge depend upon the type of current. For single phase supply, a meter charge (prepayment and conventional) of R1000 is levied. For three phased supply, the charge for prepayment meter is R2500 and for the conventional meter is R2100. These are minimum cost estimates and extra charge can be laid depending upon the actual costs. Except business rate 4, all other electricity supplies are required to pay a basic charge, as shown in Table 1. And, a single energy charge of 22.05 C/kWh for business rates 1, 2, 3 and 49.59 C/kWh for business rate 4 is levied (Table 1). Business rate 1, 2, 3 are suitable for supplies where consistently more than 500 kWh is used. The basic charge is payable each month. The business rate 4 is suitable where consumption is consistently less than 500 kWh per month. Thus business rate 4 is cheaper if the consumption is less than 500 kWh and others are cheaper when consumption is more than 500 kWh/month.

4.1.4. Tariff for farmers and rural businesses (land rate)

Under this tariff structure, fives types of tariff rates are applicable. These are; Land rate 1, 2, 3, 4 and Land Rate Dx. Land rate 1, 2, 3 are suitable for supplies where consistently more than 1000 kWh per month being consumed. The basic charge is payable per month. Land rate 4 is suitable where electricity consumption is less than 1000 kWh/month and here the supply size cannot exceed 16 kVA. Land rate 4 is for domestic or small supplies on farms. The basic charge is levied per month. The Land Rate Dx is applicable to very low usage single-phase supplies where the supply capacity is limited to 10A. This is typically suited for small telecommunication installations where electricity charge is low enough not to warrant metering for billing purposes. In this case, only a fixed charge of R279.78 per month is payable.

In each case, a deposit equivalent to three consecutive months's electricity bill is demanded. The charges for meters vary. For single phase supply (conventional or prepayment meters), the meter charge is R1300. The charge for conventional meter for three phase supply is R2600 and for prepayment meter, R2950. The prepayment meter is thus a bit more costly. In many rural areas, Eskom has to construct line to provide electricity to customers, this entails extra cost burden on consumers in terms of extra monthly rentals. The cost estimates for laying the line are as follows: three phase line R54,545/km, single phase line R30,000/km.

4.2. Cost estimates and scale economies

Two sets of population were surveyed to estimate the cost of prepaid electricity to household to individual household: (1) Some 30 households in Kwandengezi and Shongweni areas, an area outside Durban city in Kwazulu Natal ; and, (2) some 20 households in Witbank in Mpumalanga province.The average costs for meter or connection fee varies significantly from one area to another. For example, the average cost of meter in Kwadengzi area was R150 per household while R500 per household in witbank area. The average fee for South Africa is about US$15. This is a subsidized price. The full cost price can be up to $60 or more. In Witbank area, we found that some households were not charged at all because they were fully subsidized. The average prepaid electricity consumption is R80 to R150 per household in Kwadengzi–Shongweni and Witbank areas. The electricity charge comes to about 36 C/kWh.

In the surveyed samples in Witbank area, some 10% households were using prepaid electricity for small businesses and pump irrigation. The monthly expenditure on electricity in these households ranged from R1000 to R2000 per month. For business use, in the Witbank area, the users accepted that economies of scale are realized. As the consumption of electricity increases, the cost per unit of electricity declines. Inquiries with managers revealed that it all depends upon the tariff structure. Mostly for small consumption, scale economies are a rare thing.

Cost studies in Eskom show large variations in cost of service to customer per month. This needs to be reduced while maintaining an acceptable level of service. The appointment of agents for Eskom has been found to reduce cost of service; this is due to sharing of labor and infrastructure costs. This method of cost reduction has proved successful where implemented. In future, costs could be reduced by introducing automation on-line metering. The costs of vending infrastructure can be reduced through the sharing of electronic infrastructures with other bodies such as banks and retails chains who also had to install electronic fund infrastructures.

5. Advantages and disadvantages of prepaid electricity to different stakeholders

Prepaid electricity has benefited both the supplier (Eskom) and the consumer (customers). These advantages accrue in various forms and contribute to efficient functioning of the electricity production, distribution, and revenue generation function. There are numerous advantages to Eskom from prepaid cards. Some of these include the following: (1) Improving customer's service as it eliminates billing delay and no account posting or additional billing system required. (2) Prepayment is upfront that improves the cash flow of the business. (3) Cost of meter-reading is cut as no meter readers are required. (4) It can be also used to recover bad debts. In Eastern Cape, every time when a customer buys a prepaid card, pays 15% towards redemption of old debt. (5) It eliminates the disconnection and reconnection fees and administrative hassles associated with these problems. (6) It is easy to install prepayment meters than conventional one. It costs less to Eskom and to customers as well. (7) It is easy to control fraud with the help of prepayment meters. (8) There is no need to hold customer's keys as is required under conventional metering. (9) Eskom does not need to access the customer's property and thus life risk to its employees is reduced. This is particularly important in South Africa as being a very crime ridden society and where big income divide between black and white people exists. (10) It also eliminates the danger of inaccurate meter reading and thus Eskom has no more such complaints. (11) The prepayment electricity system finally improves the revenue management system of Eskom.

The prepaid system also has advantages to consumers, which include the following: (1) The consumer has a better understanding of how much energy is being consumed. This enables one to cut the unnecessary use and economy turning off lights, geyser, and other electricity-based instruments. (2) Control of energy use and budget management goes hand in hand. The more one economizes on energy use, the better one manages one's budget. (3) The consumer can buy tokens at the time and place that suits him or her. (4) There is no cost for disconnection/reconnection and no waiting for reconnection. (5) The consumer does not have to make deposits. (6) It also enables and empowers the consumer to pay back her/his debt.

However, there are disadvantages to Eskom associated with the use of prepaid cards. Some of these are as follows: (1) Based on interviews of senior managers, it is now being felt that the cost of maintenance of prepayment meters is not going down, rather it has gone up because of some unanticipated problems that have cropped now. (2) Prepayment cannot handle large size currents at this stage; therefore, it is not always the best solution. (3) Prepayment technology has not necessarily solved the problem of pilferage, although it has lessened the incidence. Revenue losses from pilferage are still high and estimated to the tune of R51 million per annum (Ngwenya, 2001).

There are also disadvantages experienced by consumers of electricity through the prepaid system that are as follows: (1) Based on interviews of users, prepayment is seen as an instrument to control the communities. However, this view is only prevalent in highly politicized communities such as SOWETO in Johannesburg. (2) Many users considered it as a big hassle to buy electricity frequently and consumed their time and heightened their worries of not having power in the house.

6. Factors affecting the success of and impediments to the expansion of prepaid electricity

The success of prepaid electricity depends upon a number of factors, which finally produce a viable system. This requires proper planing and management of resources, and a careful marketing campaign to increase the market size, among others. Several impediments that exist in the expansion of the prepaid electricity are also highlighted here.

6.1. Factors affecting the success of prepaid electricity

The success of the prepaid electricity experiment in South Africa can be attributed to better planing and management of resources by Eskom and a careful media campaign, among other factors. Two important factors affecting the success are (1) better planning and (2) good marketing campaign.

6.1.1. Better planning and management

A careful planing is must for setting up a successful prepaid electricity system. Some of the actions that need planing are as follows; tender specification, selecting a prepayment system, staff training, marketing campaign, selection of vending sites, contracting of vendors, revenue management, installation of equipment, maintenance, and daily administration.

Selection of compatible components of a system is necessary to ensure the efficient revenue management. This means the meter, the payment system, and management tools should be aligned well. It also demands that the smooth flow of information between meter, vending machine, and the databases, should be ensured. Only a complete system ensures efficient revenue management.

Similarly selection of prepayment system demands the specification of the following; procedures for revenue collection, data required for management, reports and maintenance, as well as emergency credit, friendly credit, required tariffs and taxes, compatibility to systems, hardware requirement, vendor selection, and numbers of customers to be served.

The sophistication of prepayment system requires staff training on different levels such as management, system administration, installation teams, maintenance teams, customer service staff, vendors, and vending operators. All employees need to understand different aspects of the prepayment system in order to complete the task.

A successful marketing campaign should be planned. Selection of vending sites and contracting out to reliable vendors has to be done carefully so as to increase demand for prepaid electricity. Contracts need to be set up with vendors before start of the operation. Eskom's research had revealed the following with respect to the prepaid electricity service: (1) The point-of–sale image and the personnel operating the equipment must be trustworthy in the eyes of customers. (2) The system must be secure so that tokens are not used by others. (3) The point of sale should be available for vending during the time periods convenient to the customers. (4) The activity of buying electricity (getting to the vending sites, buying and getting back) should not take more than 30 min. (5) It should be easy to purchase electricity and customers of any reasonable age should be able to identify their meter and specify purchase. Children are the main purchasers at the point of sale and purchase is often a convenience purchase (not specifically planned for buying electricity and is similar to making errand of buying cigarettes at the local super market).

The other important task is to streamline the revenue management system. This requires selecting a system manager and appointing supervisors. All system operators need to be trained. The SMS need to be configured to the needs, and compatibility with other information technology system need to be checked. Also, ensure the implementation of security measures. And, finally policies and procedures with respect to housekeeping of database, running of reports, communication with vending station, should be streamlined.

Installation of equipment is another task that needs careful planing. This requires setting up the installation teams and preparation of appropriate tool kit. It is very important to determine timings for each installation and installation team should answer customers' questions. The staff should be trained in the fault-finding and product testing. The performance measurement of staff and adjusting their plans and giving feedback to customer base are some other exercises that must be done from time to time.

Ongoing maintenance is one important key to success of the prepaid electricity management. This can be ensured by setting up a meter maintenance center with required tools such as credit reader, the ED verifier, and the engineering workstation. At the same time, one needs to define the procedures on how to handle inquiries and meter change-outs.

The daily administration of prepayment electricity is needed to ensure smooth functioning. This requires that sufficient provisions should be made for emergencies such as hardware failure, power outages, etc. Procedures should be clearly defined for emergencies, archiving of data, backing up data, and running of exception reports. In addition, regular training sessions for the staff should be conducted timeously.

6.1.2. A good marketing campaign

The prepayment system is a relatively new innovation in the electricity industry and not well-accepted yet. This requires a good marketing campaign. Eskom has taken to a good marketing campaign to reach out to its customers in both urban and rural areas. The major purpose of marketing campaign is to engender consumer acceptance and appreciation. A multi-pronged approach has been followed by Eskom. This has been done by:

- Advertizing themes.
- Media (TV, radio, mail shots, brochures, posters, etc).
- Public meetings.
- Encouraging participation of local community leaders.
- Encouraging the demand by developing an effective supply of prepaid electricity.
- Emphasizing the benefits to the consumer.

Various advertizing themes have been used by Eskom to popularize the consumption of prepaid electricity. For example, these include:

"Making your life easier"
"Electricity at your convenience"
"No more shocking bills/accounts"
"Putting you in control of your electricity costs"
"Pay as you go", and so on.

These themes have been communicated to the targeted public by way of various media means such as television, radio, mail shots, brochures, posters, public meetings, among others. Local opinion leaders have been involved in the program to increase participation of general public in the expansion of prepaid electricity.

Marketing of the benefits of prepaid electricity requires that consumers develop an appreciation of this facility. Thus, they need to be made aware of advantages of prepaid electricity. The benefits of being in control of their budget is the prime advantage of this system. Consumers decide how often and in what value they wish to buy the electricity. Should they forget or not be able to pay for their electricity, they will not be physically cut off by Eskom. They will not have to wait to be reconnected and no reconnection fee is paid. They no longer have to understand and pay accounts or bills.

Marketing campaign is not just aimed at not only convincing the customer about the advantages of prepaid system but also to educating consumers about the prepaid electricity. Customers should know how to use the product; for example, how and when to purchase credit, how to read the ED and to know when to repurchase credit, how to clean the ED, what to do or who to contact if they experience problems, and finally to know how much credit they have available at any time, and so on. Consumer education is therefore made a part of marketing campaign.

The other part of media campaign is to encourage the demand for electricity. To encourage demand for electricity, we should know that most of the prepaid electrification falls in deep rural areas; and, this requires promotion of electricity uses. These customers do not always have the appliances to use electricity. There is thus need for developing the cost-effective appliances and promote their use. One way to do so could be in terms of Eskom developing partnership with appliance manufacturer or distributor. The connection fee or deposit can be used to purchase a hot plate stove. The appliance manufacturer provides a discount coupon with every ED which can be exchanged for electricity. The customers are shown demonstrations on how to use the appliances and given donations or prizes in the form of appliances. In many places, the vendor acts as agent for appliance manufacturer.

6.2. Impediments to the expansion of prepaid electricity

Prepaid electricity was initially launched to meet the homelight needs of the rural areas that were sparsely populated. Early research by Eskom indicated significant cost savings by switching to prepaid electricity by abating the cost of billing, meter reading, and meter repairing. Besides it added to convenience by reducing the risk of security to Eskom employees who had to visit peoples' houses at odd hours. Savings were also expected to be realized in the form of decreased level of pilferage through meter tampering. The introduction of prepaid electricity solved these problems to a great extent. However, new maintenance problems, which were not visualized at the time of initiation of the project, have cropped up. The new maintenance problems are related to meter tampering. vendor fraud, and meter failures/replacement. In terms of severity of the problem, the meter failure comes the first, the vendor fraud is the second most pressing problem, and the last and least severe is meter tampering.

The prepaid program was started about 10–12 years ago. The new meters were installed with an expectation that they will last long. Eskom is now expecting a high rate of meter failures, leading to extra cost of replacement. Interviews with senior managers indicated that it is the most important and costly problem that Eskom is facing right now. Since the cost of replacement of meters is falling on Eskom, it has become a costly operation.

The second most concerns are the vending fraud. Eskom has to depend on various vendors to sell electricity to its consumers. Normally there are a number of agents in an area who buy electricity from Eskom and sell it to consumers. Over the past years, Eskom management has realized that many vendors are entering into fraudulent reporting of electricity sales. Thus revenues collected from consumers are not channeled back to Eskom. In point of fact, this is being considered as the biggest impediment in the expansion of prepayment technology. To thwart the problem, Eskom is now trying to develop a national level organization which can deal with the demand for vending from Eskom.

The third most pressing problem is the meter tampering. The tampering of meters can be done by pin or magnet. An office pin or safety pin is inserted under the plug of the circuit breaker. The pin is inserted in the gap between the circuit breaker and the bottom of the shunt. The method works well in all circuit breakers making it possible to customers to steal electricity. The usage of this method is evident by the marks left under the circuit breaker when the pin is removed. To circumvent the problem, Eskom contrived the circuit breaker tamper covers on all makes and models. On the other hand, the magnetic tampering method entails a process where magnet is fixed under the plugger circuit breaker while it is on. The magnet produces a magnetic field, which is stronger than that of the circuit breaker trip coil. This prevents the trip breaker mechanism from operating by not allowing the trip coil to pull the mechanism with its own field of strength. The tamper covers were also used to prevent the magnet tampering. The tamper covers have helped reduce the electricity pilferage to a great extent.[5]

However, simple technological improvements such as tamper covers cannot be attributed to the trend of declining meter tampering alone. Eskom has introduced infrastructure audits of meters from time to time. This has been adding to the cost. As a result of the improvements in technology (tamper cover) and audits from time to time has certainly produced some better results (Anonymous, 2001). During the last 4–5 year period, only 3–4% of meters are tampered and estimated loss of electricity vary between R51 and R100 million annually (Based on interviews of mangers and Ngwenya, 2001).

6.3. A brief assessment of expansion of prepaid electricity

A cursory examination of the expansion of the prepaid electricity reveals that it has grown very rapidly. The prepaid program was started sometimes in 1992, since then Eskom and other agencies have carried out the task of installation of millions of EDs in South Africa; the targets are given in Table 2. Almost all of these targets have been achieved. It is estimated that some 3 million more homes would be electrified by the year 2000 and beyond, thus enhancing the standard of living of half the population of South Africa. These customers whose homes are electrified are predominantly poor people. Initially Eskom had problems in carrying out the task as many who subscribed to prepaid electricity thought that it was of inferior quality electricity, compared to that supplied to white people.[6] This resulted in slow takeoff but advertizing and education campaign by Eskom changed the perceptions and prepaid electrification grew very rapidly. The process of electrification is now slowed since 2000 as the majority of domestic consumers are all electrified and the remainder is prohibitively expensive to electrify as they are located in deep rural area.

Table 2
Number of prepaid meters (in thousands) installed by Eskom and other agencies, 1992–2001

Year	Eskom	National target
1992	146	NA
1993	205	250
1994	271	350
1995	328	400
1996	316	450
1997	285	450
1998	301	450
1999	299	450
2000	256	NC
2001	200	NC
2002	160	NC
2003	100	NC
Total	2867	2800

Note: NC—not committed.
Source: http://www.eskom.co.za/elctrification/faq.htm

7. Some lessons learned

The lessons learned from the South African experience are many and we can group them under six categories.

7.1. Lesson 1: benefiting large masses of small and dispersed consumers

Some 50% population of South Africa lives in rural areas; and, most of these areas did not have electricity—the basic amenity for the 21st century standard of living. The new democratic government aimed at producing

[5] Eskom went through a number of schemes to curtail tampering. For example, in the early phase the magnetic card were replaced by numerical keypads; photocells were placed inside the meters to detect the opening of meters; electronic circuit was designed to detect all kinds of tampering. Split meters were used. To prevent cable tamper, Eskom used a stiff concentric cable with the armor shielding acting as the neutral conductor. However, no solution is completely tamper-proof.

[6] Some more than 90% people who subscribed to prepaid electricity were living in rural areas and have very little income and almost illiterate.

electricity for all so as to right the mistakes of apartheid. Installation of prepaid meters has taken place with an amazing speed. Between 1994 and 1999, Eskom has installed some 300,000 new prepayment meters every year, totaling to about 1.8 million meters. In addition, local supply authorities also have installed in their own distribution areas. By 2000, some 3.2 million prepaid meters were installed in South Africa by Eskom and local supply authorities/municipalities. This comes to roughly installing about 1000–1500 meters per working day (this was up until 2000). The majority of these meters went to new customers, i.e., previously non-electrified houses in South Africa. However, still some 2.1 million rural households remain without electricity in South Africa. Approximately 46% of rural areas have been grid electrified as opposed to 80% of urban areas. The prepayment electrification has slowed down since 2000 as further expansion of grid electrification is too costly to undertake by Eskom and other local authorities. A number of factors contributing to this include: (1) high cost of grid electrification in rural areas, (2) low electricity consumption with very little ability to pay off consumers, (3) no big anchor consumers. To supply electricity to deep rural areas, the government has therefore initiated a project for non-grid electrification through regulation.

7.2. Lesson 2: empowering consumers

Prepaid electricity has in a way empowered small and dispersed consumers in South Africa by various ways. The traditional billing system required a good infrastructure and a good ability to pay for electricity. This means only consumers who had fixed addresses, bank accounts, had postal addresses, could receive the benefit of having electricity. The prepayment omitted the problem of billing to customers, problem of connection and disconnection of supplies in the event consumer fails to pay his/her bills in time. Hence, consumer has got a better understanding of how much energy is being used. This enables one to cut the unnecessary use and economize by turning off lights, geyser, fans, and other electricity based instruments. The control of energy and budget management go hand in hand. The more one economizes on energy use, the better one manages one's budget. Consumers thus abate unnecessary use of wasteful energy.

7.3. Lesson 3: empowering eskom

Prepaid electricity has not only empowered consumers but it has also strengthened the position of Eskom in many ways. For example, the day-to-day management and maintenance of conventional meters in rural and semi-urban areas became an impossible task for Eskom, mainly because of socio-economics-related and social-attitude problems. Eskom had a difficult time managing the conventional meters. Eskom used to hire workers whose main task was to read meters and disconnect electricity of those whose payments were overdue. This entailed ensuring the transportation from house to house and the protection of its employees in the event they were harmed by the people. This all added to the cost of management of conventional meters. Furthermore, consumers tampered with meters to use electricity illegally, adding repairment cost to Eskom. In fact, Eskom was not able to repair the breakdowns efficiently and this made the day-to-day management cost prohibitively high. The conventional metering, in the absence of proper social attitudes to electricity, became very high maintenance demanding system. The prepaid metering reduced this cost tremendously. It, however, has not solved the problem of pilferage and unauthorized use completely. This innovation cut the cost of hiring meter readers, their transportation, and above all the risk of life and resultant cost to Eskom. Besides solving the day-to-day maintenance problem, the prepaid electricity improved the cash flow and eliminated the problems of disconnection and reconnection all together. Thus the revenue system was beefed up. The new system thus empowered Eskom by reducing its transaction cost significantly. In brief, the transaction cost related to billing, deposit management, postage management, bad or non-existent addresses, large up-front connection fees, etc., were altogether done away with. Life-cycle costing studies have shown that prepayment is now proving a more cost-effective option of system operation then billed system for Eskom, at least in the short- to medium-run period.

7.4. Lesson 4: advertizement and the initial subsidy has played an important role in popularizing prepaid electricity

When Eskom initiated the prepaid electricity program in 1992, it encountered several social and economic-resistance to the spread of the technology. Many early consumers of prepaid electricity, who were primarily black Africans in rural or semi-urban areas, considered the technology unfair and of poor quality as compared to electricity supplied to the white community. There were mixed feelings among many individuals; this resulted in slow take-off. To fine-tune attitudes towards prepaid electricity, Eskom initiated a massive advertisement and media campaign to sensitize about the importance of using prepaid electricity. This was done by using a multi-media approach and various advertizing themes. Various media means such as television, radio, mail shots, brochures, posters, public meetings, discussions with public groups with the involvement of local leaders are tried. The major idea was to develop an appreciation of prepaid electricity in consumer's mind.

The marketing campaign was not just directed at convincing consumers but also included educating consumers about prepaid electricity. This means that consumers were taught how and when to purchase credit or tokens, how to read the ED and to know when to repurchase credit tokens, how to clean ED, what to do and who to contact if they experience problems and finally to know how much credit is available at any time. Consumer education was therefore made a part of marketing campaign.

7.5. *Lesson 5: prepayment is not necessary a well-received innovation in all segments of society*

The discussion with various Eskom managers reflected that prepayment is not necessarily well received in all parts of the country. In some highly politicized areas, prepayment is viewed by the people as a means of control by Eskom or government. For example, the highly politicized areas of Soweto near Johannesburg, the prepayment technology has not been accepted well and residents have insisted on conventional metering system. One major limitation of prepaid electricity is that current prepaid meters can handle electric supply of 65 kV. This means it cannot handle high loads. However, as consumers start enjoying the convenience produced by electric supply, they tend to increase their consumption by switching to various types of new electric appliances. This can be considered a negative point with respect to technology. However, social unwillingness to use prepaid electricity primarily stems from the political power a society enjoys among politicians, and this gets translated into rent-earning activity.

7.6. *Lesson 6: prepaid electricity is not necessarily cheaper than conventionally billed electricity*

Prepaid electricity was initially launched to meet the homelight needs of the rural areas, which were sparsely populated. Early research by Eskom indicated significant cost savings by switching to prepaid electricity by abating the cost of billing, meter reading, and meter repairing. Besides it added to convenience by abating the risk of security to Eskom employees who had to visit peoples' houses at odd hours. Savings were also expected to be realized in the form of decreased level of pilferage through meter tampering. The introduction of prepaid electricity solved these problems to a great extent.

However, new maintenance problems that were not visualized at the time of initiation of the project, have cropped up. The new maintenance problems are related to meter tampering, vendor fraud, and meter failures. In terms of severity of the problem, the meter failure comes the first, the vendor fraud is the second most pressing problem, and the last and least severe is meter tampering.

The prepaid program was started about 10 years ago. The new meters were installed with an expectation that they will last long. Eskom is now expecting a high rate of failure, leading to extra cost of replacement The second most concerns are the vending fraud. Eskom has to depend on various vendors to sell electricity to its consumers. Normally there are a number of agents in an area who buy electricity from Eskom and sell to consumers. Over the past years, Eskom management has realized that many vendors are entering into fraudulent reporting of electricity sales. Thus revenues collected from consumers are not channeled back to Eskom. In point of fact, this is being considered as the biggest impediment in the expansion of prepayment technology. The third most pressing problem is the meter tampering. The tampering of meters can be done by pin or magnet. The tamper covers were used to prevent the tampering in conjunction with infrastructure audits.

However, simple technological improvements such as tamper covers cannot be attributed to the trend of declining meter tampering. The statistical meters are installed as well, which measure the energy flowing into an area. This is then balanced with the energy sold. This then helps Eskom to prioritize areas for auditing. Eskom has introduced infrastructure audits of meters from time to time. This has been added to the cost. As a result of the improvements in technology (tamper covers) and audits from time to time, electricity thefts have gone down significantly. During the last 4–5 year period, only 3–4% of meters are tampered. The estimated loss of electricity through illegal means is placed around R51 million per annum. In brief, prepaid system may not necessarily be the cost-effective system in the long run because of increased costs and due to auditing and technological improvements required.

8. Conclusions and prospects for developing countries

The Prepaid experiment of South Africa is a noble one. In a very short span of time (3–5 years), the Eskom could connect to many small and dispersed consumers of electricity. During these years, South Africa developed a sound technological and logistic framework for this experiment. One key task was to standardize the prepayment meters and vending system. Thus the CVS and STS were developed. Furthermore, it was found that small and dispersed consumers had a very low ability to pay and there existed a lot of variation in the payment abilities. To solve this problem, Eskom invented various tariff schedules which could accommodate the specific needs of the people. The experiment took off very rapidly as benefits of the prepaid electricity outweighed the costs and inconveniences it caused to people. Several factors can be attributed to this rapid expansion; these include: (1) better planning and management by the Eskom; (2) a marketing campaign; (3) a good set of pragmatic policies. This does not mean that it was all success. Several factors emerged as the system was developed which impeded the expansion of the prepaid electricity. However, the expansion was not problem free. Various sorts of problems were realized. For example, many maintenance problems were not visualized in advance and it cost a lot to Eskom. Vending fraud was another problem. Similarly meter tampering became other problem. Most of these problems were related to creating viable and stable institutions. Several lessons are summarized from this experiment by the authors. These are listed below:

- The experiment benefited large masses of small and dispersed consumers.
- It empowered the weak consumers.
- It empowered the Eskom in tackling a large social problem.
- Advertizement and the intial subsisy played an important role in popularizing prepaid electricity.
- Prepayment is not necessarily a well-received innovation in all segments of the society.
- Prepaid electricity is not necessarily cheaper than conventinally billed elctricity.

The prospects of prepaid electricity, especially in rural areas, in the developing countries context are expected to be good. Several advantages would accrue to the developing society and power sector in general. Lessons from South Africa can be used to estimate the prospects for prepaid electricity in the developing countries. One important developing region where prepaid electricity is being adopted is India where advantages can be seen in terms of improved cash-flow for the Indian State Electricity Boards. This would help abate the financial crisis that many SEBs are now facing. Other maintenance costs to the SEBs and the problem of rent extraction by meter readers will also be eliminated altogether. With prepayment system in place, and taking South African experience into account, it is highly likely that electricity pilferage would be reduced to a very minimum. And, at the same time, this will enable the SEBs to eschew the flat tariffs that had been in place for a very long time, and would permit increasing tariff rates. In over all, it will enhance the revenue and cut down electricity pilferage.

The possible problem that can arise in transplanting this technology in the developing world context is the possibility of increasing frauds, in particular, in the vending sector if preventive steps are not taken from the very beginning. Vending frauds have been a severe problem in the South African context. For instance, developing countries can use this South African experience to their advantage by designing a credible management system from the outset. One way to do circumvent this problem is to assign this task to reputed and large organizations that can stand by their credible commitments.

The important task for developing countries adopting this system would be to develop strong and durable prepaid meters that would suit to their particular environments. In the South African context, the replacement of meters after 10 years has cropped up as a major problem. Since this cost is not shared by the consumers, prepaid electricity becomes a costly venture. The developing world can stave off these problems from the very beginning by choosing and investing in the development of better prepaid technology, especially the vending and metering ones.

The new technology concept—the remote metering or on-line metering—is in the offing. This is like the cell phone. Remote or online metering is essentially a communication to the meter from a remotely located point of sale. The principle of operation is like that used in the smart card banking. A person wishing to buy electricity would go to a vending station. A vending station can be a vending terminal similar to current banking machine. Transactions (tokens) for meters would be generated by the vending equipment/authorities. These tokens (which exist electronically) are routed to the transmission controller for the cell to which they belong. The transmission modules handle all tokens according to priority and additional transmission information, appended to the tokens. Service commands, for example, would receive higher priority and are queued for transmission immediately. The transmission control module handles all encryption of tokens and will be a secured system. The transmission control module broadcasts the tokens to the cell.

This possesses various advantages. One, the consumer is not required to be physically present at his/her meter in order to effect the transaction. There is no need to buy token. Two, credit purchases cannot get lost as they do not exist physically. Three, this enables the distributor to apply the time of day tariff or emergency control measures. Four, the problem of non-payment can be eliminated altogether.

The prepaid electricity can be promoted by using a differential charge if it were used for ground water abstraction. This could enhance the adoption of prepaid electricity by farmers for pumping the ground water to their fields.

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