ISSN: 2395-1664 (ONLINE)
DOI: 10.21917/ijms.2019.0134

LEVERAGING SMART ICT TECHNOLOGIES FOR IMPROVING ENERGY UTILIZATION EFFICIENCY IN SELECTED INSTITUTIONS IN UGANDA

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Abstract
This study investigates the key issues and challenges in monitoring and controlling energy consumption in Uganda's public institutions. It also explores the potential of improving energy efficiency in these institutions through adoption of state-of-the-art ICT technologies to monitor and control energy use at individual unit or department level. This includes views and perceptions on the potential benefits and costs involved. The research study is a cross-sectional study that is based on both descriptive and quantitative data. The descriptive approaches were used for obtaining narrative information and descriptive statistics that were used to illustrate and back up inferences on relationships between the study variables based on the quantitative data. The quantitative approaches were used to deduce the existence and significance of relationships between the variables being investigated. A general finding is that apart from some managers, most energy users at the public institutions are not aware of how much energy they use and what it costs. Though the high cost of energy was felt at the higher management levels, most of the users did not seem concerned about the cost and energy inefficiencies. There is also a glaring lack of awareness on smart ICT technologies that can be used to closely monitor and control energy use at individual unit or department level or lower levels. The public institutions take on aggregate energy use bills without requiring accountability of the various units/departments within these institutions.

Keywords:
Smart ICT, Energy Utilization, Energy Efficiency, Uganda

1. INTRODUCTION

With rising urban populations and increasing socio-economic activity, Uganda is faced with the challenge of minimizing energy costs and ensuring its efficient usage [24]. Moreover, there has been a rapid increase in the number of energy consuming devices and appliances, driven by advances in technology and innovations. In addition, there is a steeply rising peak energy demand curve as indicated in the diagram below, and this has been attributed to increase in Uganda's energy exports [35].

Uganda's electricity distribution grid has been grappling with challenges of vandalism, illegal connections and energy losses of which make the electricity expensive, unreliable and unstable. Efforts are being made to reduce the distribution losses, which ranged between 38% and 40% in 2002, to a target of at most 14.3% by 2018 [28]. This implies that losses that were not previously metered have to be borne by those who pay the bills.

Yet the subject of energy monitoring in institutions has not yet gained wide discourse in the country. Most institutions and individuals do not know what they are spending on energy until they face the bill. This should not be so, because it is possible that even with identical units the consumption the energy consumption can differ by a factor of two or more depending on how the users behave [2].

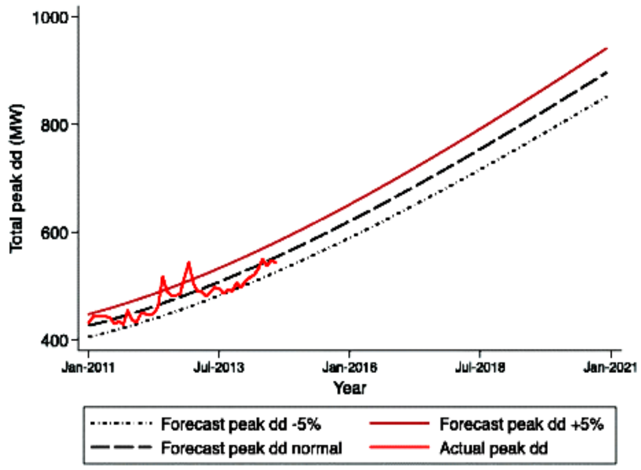

Fig.1. Projected Peak Energy Demand (dd) [35]

Current metering systems in the country only provide an aggregate bill and do not provide management with real time or analytical data on how individual units or sub-units consume the energy. Accordingly, the institutions are prone to making losses due to the inability of individual units to account for the energy they use, which encourages irresponsible behavior and also gives room to illicit use or tapping of the electricity. By contrast, institutions in more developed countries have already adopted modern technologies to monitor all aspects of energy utilization, and there is even an ISO 50001 international standard to guide institutions on energy efficiency and energy management systems [14] [17] [20]. There is wide application of energy monitoring and control systems in both institutions and homes. Systems that use a combination of GPRS, SMS, Internet, micro-controllers, relays and related mobile technologies do not only perform the function of monitoring but also provide automations such as remotely switching on and off of appliances such as lights, air conditioners, water heating systems, etc., even when one is miles away from the appliance [26] [37].

In view of the above consideration, this study was carried out to investigate the potential for leveraging the power of ICT to monitor and control electrical energy consumption in selected public institutions of Uganda. Even with the implementation of public sector reforms, public agencies in Uganda are still entangled in practices that are considered to be obstacles to efficiency [3]. Among these inefficiencies are poor performance management practices, weak records management, and poor work culture. Some of these institutions have made significant efforts to address these inefficiencies [15]. However, efforts to improve energy efficiency in these institutions through implementation of best energy savings practices and attainment of management systems standards such as ISO 50001 have not been documented.

With on going public sector financial reforms such as Treasury Single Account (TSA), implementing the Output Based Tool (OBT), budget monitoring, performance reporting and directly transferring funds to service delivery units, it becomes imperative to have robust systems that enable close monitoring and transparent control [33]. There has been no research evidence to indicate whether such robust systems have been implemented for establishing appropriate energy management systems in the public institutions of Uganda. Little is known on how these public institutions monitor energy consumption in their various units. It is necessary to establish how much they can gain or save by applying modern ICT-based energy monitoring and control systems instead of just relying on bulk metering systems. Accordingly, this study contributes to knowledge on how public institutions in Uganda can address the need to monitor and control energy utilization. The study sought;

- To investigate key issues and challenges in monitoring and controlling energy consumption in Uganda's public institutions;
- To explore ICT-based options for enhancing the monitoring and control of energy in Uganda's public institutions in view of enhancing the accountability of individual units and eliminating leakages;
- To assess the potential costs and benefits of adopting state-of-art ICT solutions for monitoring and controlling energy utilization in public institutions of Uganda; and also
- To derive policy recommendations for enhancing energy efficiency and energy savings in public institutions of Uganda.

2. CONCEPTUAL FRAMEWORK

The conceptual framework in Fig.2 is based on the premise that application of appropriate ICT technologies and information as the independent variables, can bring out changes in factors related to energy efficiency, the dependent variables. There are intervening variables related to consideration of costs, benefits, existing technologies, policies and regulations when planning and implementing ICT related innovations to bring about the desired energy efficiencies. There are also external factors, as indicated in the conceptual framework. This study mainly focuses on the independent, dependent and intervening variables indicated in the conceptual framework.

3. RELATED WORKS

3.1 ENERGY MONITORING ISSUES AND CHALLENGES IN UGANDA

To address rampant power thefts and leakages in Uganda, pre-paid meters were introduced for households, and bulk metering was introduced for micro and small-scale enterprises (MSEs). A key observation made is that government and utility companies introducing such measures tend to focus on technologies, whereas the behavioral factors such as social norms and trust, as well as social learning and first-hand experience with the technologies, can play a significant role in determining the success of the technologies [37].

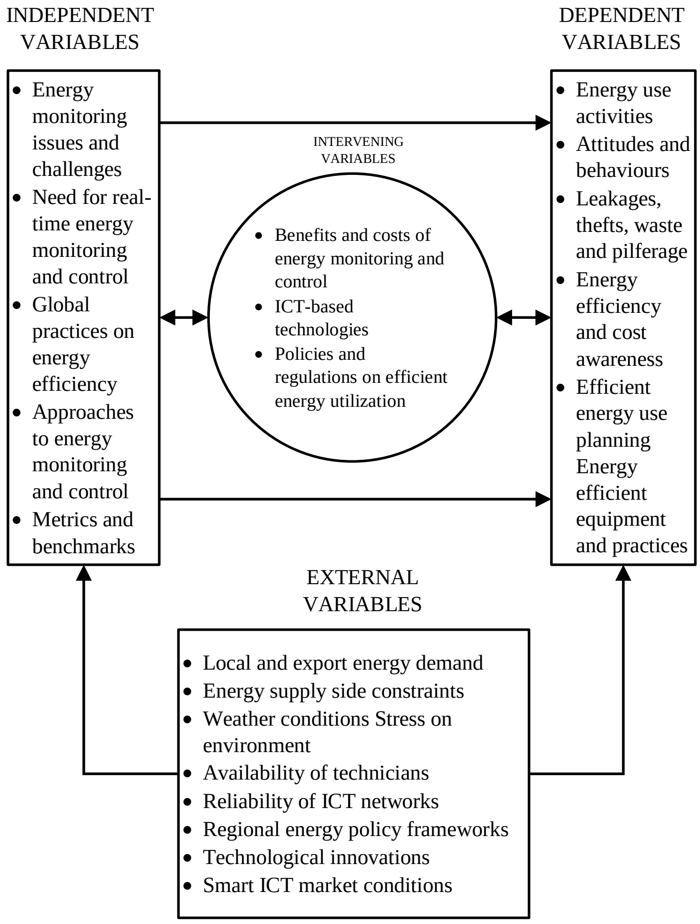

Fig.2. Conceptual framework

Legacy energy monitoring systems tended to be complex and non-user friendly, which tended to limit their full appreciation and effectiveness. In addition, they were not generating real-time data that could provide timely feedback to users to facilitate corrective action. A study on developing a real time energy monitoring platform in a University [1] indicated three essential features of a user-friendly interface, namely: 1) A screens where signals on energy parameters (active power, reactive power, apparent power and power factor) can be seen in real time, 2) A map of the area for the on/off switching functions of the equipment involved, and 3) A database that can display analytics on a periodic basis (hourly, daily, weekly, monthly, etc.).

3.2 THE NEED FOR REAL TIME ENERGY MONITORING SYSTEMS

It is well established that monitoring of energy utilization can lead to significant improvement in the efficiency and cost-effectiveness of energy utilization, although the effectiveness and fundamentals of each design may vary [11]. Research has shown that in homes, for example, as much as 41% of the energy can be wasted due to improper and negligent use [29]. Other findings indicate that the efficiency of energy utilization can be improved as much as 35% where the awareness and need for controlling energy usage has been established among users [21]. The need for monitoring energy utilization in real time is built on the premise that measurement makes it possible to manage and control the use of energy, and that what is seen is more readily measurable.

A major feature of this study is that it was conducted in the context of Uganda where the energy consumption issues can differ considerably from those implied in many of the previous studies. For example, the weather is always favourable throughout the year and there is very limited demand for items such as ventilators, heaters and coolers compared to similar countries which experience unpredictable and harsh climatic conditions. Consequently, the factors that drive up energy costs in Uganda can be quite unique.

3.3 GLOBAL PRACTICES ON ENERGY EFFICIENCY

Globally, energy monitoring and control has been driven by environmental concerns over energy efficiency, coupled with the ever-increasing fossil fuel prices and the drive to meet renewable energy targets [7]. Accordingly, energy monitoring systems in combination with automated switching systems are being applied to automate various components such as heating, ventilation and air conditioning (HVAC). Studies on the various energy performance measures is now a major field of interest. For example, a study on the selection and cost-benefit analysis of energy efficient HVAC systems for complex building designs and usage scenarios considers use of a knowledge management framework as a mediator for pertinent software [19].

Inadequate energy monitoring data is highlighted as one of the major challenges that impede implementation of the European Energy Performance in Buildings Directive (EPBD) leading to failure to achieve the EPBD aim of reducing energy consumption [10]. When comparing energy utilization efficiencies on a global scale, there can be variances in results due to different approaches and computational methods used by various countries. But even when these variances are considered, it has been found that weak policies and weak management systems hamper energy utilization efficiencies [25].

Since power thefts and pilferage are common and can greatly reduce the energy utilization efficiency, it has been pointed out that there is a need to accurately meter and bill energy used by particular consumers, and to locate points of such power leakages, and also to estimate the actual losses caused by such leakages [16]. Benefits of improved energy efficiency that can be achieved through appropriate monitoring systems include: abatement of greenhouse gases, at least a partial decoupling of economic progress from environmental pressures, reduction of system loads and stresses, enhancing the reliability of energy supplies, financial savings, enhanced labor productivity, and many others [29].

3.4 APPROACHES TO MONITORING AND CONTROLLING ENERGY UTILIZATION

The Internet of Things is an evolving paradigm that enables automated monitoring and control of electrical devices connected to the Internet by use of Wi-Fi. A dominant technology here is the iPlug which fits into a generic socket and provides information on power utilization by devices connected through the plug. This information is stored in a database and is used to generate various analytics. The iPlug also provides information on the On/Off status of the socket to which it is connected, and can be used in conjunction with mobile apps to even remotely switch on and or off the current through it [13].

In the case of Uganda, there is very little knowledge about such modern approaches to monitoring and controlling energy consumption, given that as a developing country most concerns have been on access to energy and energy security [32]. There is a shortage of research evidence on the awareness of individuals and institutions about energy monitoring and control technologies, as well as empirical data on how behaviors and perceptions towards energy consumption can be changed by such technologies. Such behaviors and perceptions are important because they would be put in consideration when establishing interventions or policies that are aimed at reducing energy losses through applications of state-of-art technologies.

The US Environmental Protection Agency gives some guidelines that can be adopted for setting metrics and benchmarks for various types of buildings and settings. In case of laboratories, for example, guidelines on establishing energy utilization metrics include those for lighting, plug-in loads, ventilation, cooling and heating, besides whole-building metrics and benchmarks. It is pointed out that the quantitative targets and metrics need to be specified at design and programming level and then be followed throughout delivery processes [27].

However, metrics and benchmarks can be adopted for monitoring energy efficiency and energy savings, improper understanding of energy efficiency can lead to improper use energy efficiency data, generating biased judgments and evaluations. That study shows that an integrated perspective is necessary because if the goal is simply to decrease energy consumption per unit of output, energy efficiency will not be achieved in the long term due to endogenous and external factors that are likely to come into play. According to the same study, the advantages and disadvantages of the various energy efficiency indicators and metrics also need to be investigated.

3.5 ICT-BASED TECHNOLOGIES FOR ENERGY MONITORING AND CONTROL

Energy Circles gives some comparison of commercial energy monitoring systems with regard to what they measure, installation requirements, adaptation to solar and wind/net metering, display options and price, as shown in the Table below. All the options use internet, only that Blue Line requires a Wi-Fi connection.

Table.1. Energy monitoring and control systems

Product	Blue Line	Wattvision	TED 5000	eMonitor
Measures	Whole Building	Whole Building	Whole Building	Whole House + Individual Circuits (including individual appliances)
Installation	Installs on electric meter	Installs on electric meter	Installs in Breaker Box + Network	Breaker Box + Network

Solar and Wind or Net Metering	No	No	Yes	Yes
Display Options	Wireless Tabletop	PC, Smartphone, 3rd Party Displays	Wireless Tabletop (opt.) + Internet-connected Computer + Google PowerMeter	Internet-connected Computer + Google PowerMeter + Future Tabletop Display
Price	\$248	\$249	from \$239.95	from \$499

From Table.1, it can be seen that only the eMonitor option here can be applied to individual circuits and appliances, the others working only for a whole building. The eMonitor option also appears to be the most expensive of the products, possibly due to the increased flexibility.

3.6 BENEFITS AND COSTS OF USING ICT FOR ENERGY MONITORING AND CONTROL

It has been argued that systems aimed at just creating awareness and change of attitude may not necessarily provide the benefits of improving energy efficiency. Hence, adoption of practice-based models to foster the necessary energy saving culture has been proposed [30]. An interesting and common factor is the 'rebound effect' which is described as an increase in energy consumption, the opposite of what is intended by the energy saving systems. A possible scenario of this type can happen when users perceive that energy is costing them less due to improved systems, and so they are tempted to spend more than they actually need [30] [35]. More insights on the rebound effect are provided by Greening et al. [15].

According to some scholars, it is not possible for market mechanisms to attain the optimal goal of offering energy with minimum overall costs when external costs are not included in the prices of energy. There is research evidence to show that combination of ICT technologies with adequate regulatory and policy frameworks can play a significant role as a driver towards behavior change that leads to energy performance improvements. For example, in UK and EU large databases of buildings are kept for the sake of monitoring energy efficiency and regulating emissions, and display of official building energy certificates has been identified as a catalyst for behavior change [6].

Several studies have been carried to quantify energy savings and describe change in human behavior resulting from use of In-Home Displays (IHDs). In one such study, the majority of subjects continued engaging with the IHD for 37 months and showed a 27% decrease in energy consumption compared with those in a control group that did not have the IHD [44]. These findings imply that similar energy savings could be achieved by use of similar displays in public institutions.

Technomics is an emerging field of study concerned with trends in business and society resulting in observable economic change caused by the advancement of technology [23]. Three technomics laws have been considered as explanatory drivers for the rapid development and application of ICT-enabled technologies for energy monitoring and control. These are, [22]: 1) The first law of computational ubiquity which implies that cost of equivalent computing performance halves every 18-24 months; 2) The second law that implies that the cost of locating information on the global network diminishes exponentially as the size of the network increases; and 3) The third law on innovation which implies increased employee productivity and reduced optimal organization size as the cost of transactions diminish.

It has been indicated that use of an RFID system and serial communication to measure power on a 3-phase machine is much more efficient than the traditional way that relies on kWh meter and manual labor which entail high costs of manual recording by the operator. The benefits and costs of proposed energy efficiency interventions can be simulated, taking into account a wide range of parameters, including comfort, user preferences and ambience quality. Such approaches have indicated that agent-based intelligent control systems offer several advantages over traditional energy control systems. Similar approaches indicate that margin energy savings of 30% can be achieved by just optimizing system regulations [8].

3.7 ENERGY USE ACTIVITIES

It has been demonstrated that in large university campuses the electricity and water utilization patterns are similar to those found in medium-sized cities, and that it is possible to measure the relative share of energy used by various units [4]. Zhou and Yang [5] demonstrates two major research streams on energy consumption behavior, namely the economic paradigm and the behavior-oriented paradigm. This study indicates that energy efficiency utilization can be effectively improved through understanding and changing the behavior of consumers. It also demonstrates how the power of ICT technologies can be leveraged for providing big data that can provide new ways of analyzing and understanding the behaviors of individuals towards energy consumption and utilization efficiency.

It has been indicated that managing social norms and promoting organizational justice can discourage workers from illicit behavior, including thefts or negligence [9]. A study shows that electricity theft in Uganda is quite rampant, and that it costs the power distributing company UMEME Ltd. over USD 30 million annually [34]. This study identified some measures that are being taken against this, such as the introduction of prepaid meters, intensive media campaigns bundled with bounties against reported power thefts and strengthening of the pertinent law. Besides recommending multi-disciplinary approaches to address this problem, the study also proposes 3 types of ICT applications that can remedy the problem, namely: 1) Applications that communicate the cost of electricity theft to consumers; 2) Applications that enable collecting tips on power thefts; and 3) Applications that enable evaluation and managing of the theft tip information.

4. METHODOLOGY

4.1 RESEARCH DESIGN AND METHODS

The research study is a cross-sectional study that is based on both descriptive and quantitative data. The descriptive approaches were used for obtaining narrative information and descriptive statistics that were used to illustrate and back up inferences on relationships between the study variables based on the quantitative data. The quantitative approaches were used to deduce the existence and significance of relationships between the variables being investigated. The study population consisted of all public institutions in the divisions within Kampala city in Uganda, including universities, hospitals, urban authorities and line ministry departments

4.2 SAMPLE SIZE AND SELECTION

Respondents were selected from two universities (Makerere University and Makerere University Business School), one referral hospital (Mulago Hospital) and one urban authority (Kampala Capital City Authority), one-line ministry and three other public institutions. The sample size consisted of 51 respondents from the targeted institutions as indicated in the sampling frame below. A systematic sampling approach was used to select the respondents, basing on their positions and relevance regarding energy efficiency and utilization in their organisations. Thus, senior managers and heads of departments were targeted because they have overall responsibility over energy utilization in their institutions. Technical staff in charge of utilities were targeted because they have first-hand information on energy utilization issues. Ordinary staff/employees were targeted because their behaviours and attitudes are critical in determining energy utilization efficiency.

Table.2. Sample frame

Sampling Frame		
Respondents	**Number**	**%**
Senior managers and heads of departments	15	29
Technical staff in charge of utilities	19	37
Ordinary staff/employees of the institutions	17	33
Total	51	100

4.3 DATA COLLECTION

The following data collection instruments were used for collecting primary data,

- A questionnaire for the senior managers and heads of departments in the targeted public institutions.
- An interview guide for technical staff in charge of utilities in the public institutions.
- An Interview guide for the staff/employees in the targeted institutions.

Two research assistants were engaged to deliver the questionnaires and conduct the interviews. Paper versions of the data collected tools were supplemented with online versions which were particularly useful for collecting data from busy correspondents and those who could not be reached physically. Besides primary data, secondary data was obtained from various sources such as libraries, the internet, and documentation from the targeted institutions regarding energy utilization and expenditure. The following measures were taken to ensure proper data quality control:

- Preliminary testing of the data collection instruments on a few individuals and revising the instruments in case of inconsistencies or questions that might be interpreted differently by various individuals.
- Different rewording of some questions to ensure that respondents give accurate responses.
- Using personal face-to-face interviews in additional to questionnaires. This enabled the researchers to probe issues in detail where necessary.
- Alerting respondents ahead of time and possibly remitting to them the questions in advance, by email where possible, such that the respondents get sufficient time to ponder about the questions before providing responses.
- Validating the sources of secondary data by any available means, to ensure that such data is genuine and accurate.

4.4 DATA ANALYSIS

Primary data obtained from respondents was analysed using MS Excel for grouping and categorization of data as well as deriving quantitative analysis.

The quantitative analysis mainly consists of tables derived from the responses, each of which is followed by a brief explanation and discussion of the results. The latter includes a discussion of findings from the descriptive analyses. Where appropriate, data from literature and secondary sources are referred to in order to substantiate the findings and conclusions derived from the study.

4.5 FINDINGS

This section presents and discusses the major findings of this study. It starts by providing the demographics and biodata for the three categories of the respondents. Thereafter, the key findings are given under each of the key objectives of the study.

4.6 DEMOGRAPHICS AND BIODATA

Responses were obtained from 51 respondents distributed according to gender as follows.

4.6.1 Gender of Respondents:

Table.3. Respondents Categories and Gender

Gender	General		Technicians		Managers		Total
	Freq.	%	Freq.	%	Freq.	%	
Female	9	53	8	42	5	33	22
Male	8	47	11	58	10	67	29
Total	17	100	19	100	15	100	51

In the case of the technicians and managers, the majority of the respondents were male, which reflects the male dominance gender characteristics encountered in the targeted institutions. For the general respondents it was possible to balance the gender more closely.

4.6.2 Age of Respondents:

Table.4. Age of the Respondents

Age Group	General		Technicians		Managers		Total
	Freq.	%	Freq.	%	Freq.	%	

Below 20 years	4	24	2	11	1	7	7
20-29 years	10	59	4	21	5	33	19
30-39 years	3	18	13	68	9	60	25
40 years and above	0	0	0	0	0	0	0
Total	17	100	19	100	15	100	51

In the case of managers and technicians, the proportion of the respondents 30 years and above was greater than for those below 30 years. This was expected because it is the people in the higher age bracket that likely to occupy managerial positions and also have more technical experience. In the case of general respondents, the highest proportion was for those in the lower age bracket, which reflects the fact that these could be more approachable for the general respondent's category.

4.6.3 Length of Stay with Institution:

In the case of managers and technicians, most of them had stayed for 10 or more years with their institutions, which corresponds to the above age distribution of these respondents. The length of stay with the institutions was more evenly distributed in the case of the general respondents.

Table.5. Length of Respondents' stay with the Institution

Duration	**General**		**Technicians**		**Managers**		**Total**
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	
< 1 year	1	6	0	0	1	7	2
1-2 years	1	6	2	11	0	0	3
2-5 years	6	35	2	11	1	7	9
5-9 years	3	18	0	0	2	13	5
>=10 years	6	35	15	79	11	73	32
Total	17	100	19	100	15	100	51

4.6.4 Awareness on Energy Use and Energy Costs:

The 17 general respondents were asked to explain whether people at the places where they worked were aware of how much energy they use, and the costs involved. 14 of these respondents (82%) indicated that the people at the places of work were neither aware of how much energy they use, nor the costs involved. The 3 other respondents (18%) indicated that only administration was aware of the energy usage and costs, and that the rest of the workers were not aware.

On the other hand, when the 15 managers were asked to state their views on various aspects of energy efficiency awareness, their responses were as indicated in the Table.6.

Table.6. Managers' awareness on energy efficiency

Energy Efficiency Awareness	**Average Score (1-5 Scale)**	**Standard Deviation**
We seem to be spending too much on electricity	3.5	1.13
To what extent is energy efficiency considered when procuring or disposing off equipment used in your organization?	3.0	1.25
Management has information on energy consumption rates of each major equipment	2.5	1.13
People working here can tell how much electricity they have used on a certain day	2.1	0.59
The institution has historical data on each unit/department that can be used to compare energy consumption on a monthly or annual basis	2.0	0.53

The above findings indicate while most workers are not aware of how much energy they use or the costs involved, management is generally aware that the costs involved are high and can be reduced, but management does not have adequate information on how the energy savings can be achieved.

4.6.5 Existing Measures and Policies on Ensuring Energy Utilization Efficiency:

The 17 general respondents were asked about measures and policies that were being implemented in their organizations to ensure that there is no misuse of electricity and other energy sources. Two of the respondents (12%) indicated that meters had been at each building. 6 of the respondents indicated that workers were required to switch off electricity when not in use and after work. In one case, it was reported that about 4 years ago stickers had been placed on computing devices and doors to remind workers to switch off lights and other devices, but that these stickers were no longer there. 5 of the respondents (29%) indicated that there were no such measures or policies, or that they were not aware of them.

Two respondents among the managers reported that lights were normally left on in classes and offices and that there was too much energy wasted in their institutions. Another one observed that the prepaid meters (Yaka) seemed to meter more units of power used than the original meters.

The study found a general lack of awareness of specific policy measures that can be implemented by government and institutions to monitor and improve energy use in the institutions.

4.6.6 The Need for Energy Monitoring and Control in Public Institutions of Uganda:

The 17 general respondents were asked to rate on a scale of 1 to 10 the extent to which people working in their organizations would recommend installation of Smart ICT technologies to provide feedback on the energy they personally use. The mean score on this question was 6.8 out of 10, with a standard deviation of 2.14.

The 15 managers responded as indicated in the Table.7 regarding the need for monitoring energy utilization in their organizations.

Table.7. Managers' responses on need to monitor energy utilization

Need to monitor energy utilization	Average Score (1-5 Scale)	Standard Deviation
There is a need to control energy utilization efficiency here	4.3	0.82
There is a need to monitor energy utilization efficiency here	4.3	1.03
There seems to be some leakages and unauthorized use of electricity in this institution	2.9	1.49
Each department or major unit here pays for its own electricity directly	1.9	0.52

The above results indicate that both management and workers were quite aware of the need to monitor and control energy use in the public institutions and therefore they would recommend their acquisition.

4.6.7 ICT-based Energy Monitoring and Control Technologies:

In response to the question on what smart technologies can be used to monitor and control energy utilization in their institutions, the technicians provided the following information,

- Ted Pro technology.
- Energy generating stations.
- Building monitoring systems.
- LED lights and energy servers' bulbs.
- Digital energy monitoring devices.
- Remote embedded energy systems that enable on or off switching.
- Install pre-paid meters (Yaka) for every department.
- Using energy saving bulbs and equipment.
- Using solar power as an alternative to hydroelectricity.
- Use equipment with low energy consumption.
- Use circuit breakers in case of overloads.
- Use energy rationing technologies.
- Use energy saving systems or devices.
- Use self-monitoring devices which automatically switch off when the equipment is idle.
- Use automatic energy saver equipment and lighting systems.
- Use of thermostats.
- Use of digital timers that can also reduce energy consumption in proportion to the work involved.
- Using fewer computers and more monitors instead.

It was found that most technicians were not aware of ICT-based energy monitoring systems and/or the merits and demerits of the various alternatives such as those indicated in the literature review under the section on ICT-Based Technologies for Energy Monitoring and Control.

4.7 POTENTIAL BENEFITS AND COSTS OF ENERGY MONITORING AND CONTROL

4.7.1 Benefits of Energy Cost Awareness:

The 17 general respondents were asked what could be gained if by means of modern technology every worker in their organizations suddenly became aware of how much energy they use and what it costs on an hourly, daily and weekly basis. All these respondents indicated that several benefits could be achieved including savings on energy costs, reduction of energy consumptions, and reduction of administration expenses. Employees would begin to reflect on how much power they use and become responsible, e.g. by switching off lights when not in use and endeavor to minimize energy utilization. A respondent pointed out that this would contribute to corporate social responsibility, while two others indicated that this would instill the required sense of responsibility and initiatives by the workers themselves to reduce the energy costs.

Table.8. potential benefits and costs of energy saving equipment

Questions on benefits and costs	Average Score (1-5 Scale)	Standard Deviation
To what extent would this institution make energy savings by introducing state-of-art energy monitoring systems everywhere?	3.9	1.00
The institution will spend less on energy if each building unit is made to pay its own electricity bill	3.0	1.65
Energy monitoring and control systems are too expensive	2.4	1.24

Responses obtained from the 15 managers on the potential benefits and costs of energy saving equipment were as follows.

4.7.2 Response Relating to Advantages and Disadvantages of Strict Energy Monitoring and Control:

The 17 general respondents were asked to state the possible advantages and disadvantages of introducing strict energy monitoring and control in their institutions.

The major advantages given by 16 of the general 17 respondents were on cost savings and effective use of energy. The disadvantages were given as follows,

- Causing inconveniences and limitations on energy use (3 respondents)
- High costs of installing strict energy (1 respondent)
- Imbalance of activities and equipment that may require more energy (1 respondent)
- Staff demoralization (1 respondent).

4.7.3 Gains of Energy Utilization Control:

On the gains that could be made in their institutions if all forms of power leakages, waste and thefts (if any) were stopped, 13 of the 19 technicians indicated that there would be savings from reduced energy costs. In their own words,

"High savings leading to expansion of the institution."

"Reduced wastage would offer better power usage."

"The institution could save a lot of funds which could otherwise have been wasted in covering electricity bills."

"The expenditure would be cut down and the money would be diverted to other beneficial activities."

"The institution would save money on utilities and address other pertinent issues that add value to the institution say improving service delivery through improved structures and staff satisfaction."

"Money will be saved for other purposes."

"There would be no energy losses."

4.7.4 On cost of Energy Utilization Control:

On the costs that would be involved in installing modern technologies to enhance energy efficiency in their institution, the technicians provided the following answers.

Table.9. Technicians' knowledge on costs of energy monitoring and control technologies

Costs involved	Freq.	Total	%
Training costs	2	19	11
Installation costs	2	19	11
Some good money amounts	2	19	11
No idea, I don't know, Not Clear/Sure, Hard to estimate	5	19	26

The training costs reported by the technicians include the training of staff and users on the technologies involved. Three of the technicians indicated that the initial costs may seem high but that it would be cheap in the long run. Another technician who was not sure of the costs involved thought that most of the emphasis would be put on changing the mindsets of the power users and showing them how beneficial it could be through credits other than thinking of gadgets which will still be controlled or manned by individuals.

5. RESPONDENTS' RECOMMENDATIONS ON ICT-ENABLED ENERGY MONITORING AND CONTROL

5.1 RECOMMENDATIONS BY THE GENERAL RESPONDENTS

The following recommendations were provided by the 17 general respondents with regard to improving energy utilization efficiency in their organizations,

- Use of solar power, solar lights and energy saving electronics.
- Switch off lights and use natural lighting where possible
- Introduce energy saving methods everywhere.
- Introduce energy metering devices everywhere.
- Use smart technologies to detect thefts.
- Use automated systems to switch off lights.
- Sensitization and awareness creation.
- Strict energy policies.
- Update to the latest technology.
- Schedule to revise the wiring system of the institution.
- A qualified team for purchase of equipment.
- Use of biogas.

The 17 general respondents were asked to rate on a scale of 1 to 10 the extent to which they would recommend technologies that remotely switch off units that spend more energy than is planned for. The mean score on this question was 7.7 out of 10, with a standard deviation of 3.15.

The 17 respondents were also asked to rate on a scale of 5 other possible measures for ensuring efficient utilization of energy. Their responses are indicated in the Table.10.

Table.10. Measures to enhance energy utilization efficiency

Possible Measure	Average Score (1-5 Scale)	Standard Deviation
Display energy use charts	4.3	0.79
Socket power monitoring plugs	4.1	0.93
Remote socket on/off switching	3.7	1.31
Power rationing among users	3.4	1.23
Individual unit power metering	3.1	1.27
Power tapping and theft detectors	4.2	1.38
Energy efficiency detectors	4.3	0.99
Energy efficiency campaigns	4.4	1.21
More strict energy use policies	3.9	1.09

5.2 RECOMMENDATIONS BY THE MANAGERS

12 of the 15 managers indicated a need to sensitize and create awareness among staff and clients on the need for efficient energy utilization and how it can be achieved. 6 of the 15 managers indicated a need for close monitoring of energy used by each unit in their organizations. Other recommendations by individual managers were,

- Switching off lights, printers and scanners and hibernation of computers when not in use.
- Use of energy saving lights, devices and appliances.
- Auto off and on for account system.
- Reduction of cost per unit.
- Solar and other better lighting options, and a mix of solar and hydro-power.
- Identification and monitoring of equipment like computers that consume a lot of power.
- Regulating illegal users like canteens, photocopiers, etc.
- Allocation of electrical energy units.
- Power monitoring to ensure its used efficiently
- Providing a meter per department
- Creation of central switch to boost and control energy usage

5.3 RECOMMENDATIONS BY THE TECHNICIANS

Nine of the 19 technicians pointed out the need for training, sensitization awareness creation and information sharing. One of them put it this way.

"...changing people's perceptions so that they reframe their thinking towards energy consumption through trainings and sensitization. This needs to be done practically with figures so that people appreciate how much they can save when they are conscious about the costs… Sensitization of everyone. Be open on how much is spent on budget item such as electricity, maintenance etc.…"

The other suggestions by the technicians were,

- Installing electrical metering devices in each department.
- Conducting monthly reviews and categorizing (energy costs) according to the building.
- Generating alerts where more energy than necessary is being used.
- Use of sockets which enable remote on/off switching at certain hours of the day.
- Providing each unit with their power consumption bill and rating of the energy used compared to other departments.
- Putting a limit on the energy to be paid by the institution beyond which the users become liable.
- Awareness campaigns and use of notices and stickers put in convenient places.

On what needs to be done to ensure that there are no power thefts, leakages or waste in the institutions, the technicians provided the following answers,

- Encourage people to be responsible, look at power usage in the institution, and ensure that theft and leakages are curbed.
- Monitoring all units on the use of electricity.
- Use of energy monitoring tools.
- Switching off lights in classes and offices when not in use.
- Using rightful appliances and avoiding loose connections.
- Introduce the prepaid metering system (Yaka) into the institution.
- Enforcement of regulations.
- Conducting regular power audits.
- Introducing hotlines for reporting thefts.
- Install surveillance cameras.

The following are some of the statements made by the technicians with regard to this,

Good relationships between the institution and its employees helps a lot, ownership at the personal level.

"I think yaka is doing well let staff pay for their own power and decentralize power supply, central hot water boilers…"

"The government or institution can allocate every work power credits per annum so that those who use less can trade their credits to the large consumers so that it goes with an incentive. People can change with time…"

"Put in place a planning, supervising, monitoring and evaluation team of knowledgeable people."

One technician however responded that they had not yet registered any such cases of power thefts, leakages or waste.

Other means of controlling energy costs suggested by the technicians are,

- Use of sensors.
- A system that notifies the user how much energy has been used.
- Penalties for higher bills based on the usual estimated rates.
- Carrying out more supervision.
- Annual audit report per unit (power footprint).
- Decentralization and budget autonomy: "If we become autonomous and control our budgets, then we can save some money. Currently money saved on electricity cannot be diverted to another item."

6. CONCLUSION AND RECOMMENDATIONS

This study investigated the potential for leveraging state-of-art ICT technologies to monitor and control energy use in public institutions of Uganda, in view of improving energy utilization efficiency and minimizing the costs involved. It explored the key issues and challenges that need to be addressed in monitoring and controlling energy consumption in these institutions. It also explored the potential of available ICT-based technologies that can be used by the public institutions to improve their energy use efficiency, including the potential benefits and costs of such technologies. The study also aimed at generating appropriate policy recommendations that can be adopted by government and institutions to address energy efficiency uses and promote the use of appropriate ICT technologies for energy use monitoring and control in the public institutions. The main conclusions from the study are given below.

6.1 CONCLUSIONS ON KEY ISSUES AND CHALLENGES IN MONITORING AND CONTROLLING ENERGY CONSUMPTION

In general, workers at the public institutions are not aware of how much energy they use and how much it costs. This applies to both to individual workers and individual units/departments within the institutions. The managers in these institutions are aware that the institutions seem to be spending more on energy than necessary.

Apparently, most of the workers at the public institutions seem not to be bothered or concerned about how much the institutions spend on energy. The findings indicate that there is a perceived need by managers to initiate efforts to change attitudes and behaviors towards energy use efficiency.

Apart from occasional reminding of workers to switch off equipment when not in use, there are no systematic or sustained efforts to remind users at the work place to be mindful of energy use efficiency.

The public institutions tend to take on aggregate energy use bills without requiring accountability of the various units/departments within these institutions. This situation contributes to the don't-care attitudes and behaviors regarding the amount of energy consumed or wasted.

The biggest consumers of electricity in the public institutions are computer-related equipment, refrigeration equipment and kitchen cooking equipment. This finding suggests that these are the priorities areas that the institutions should target primarily when taking steps to improve energy utilization accountability and efficiency.

The procurement of equipment used in the public institutions apparently does not take into consideration the energy efficiency of the equipment used. This results into higher energy costs that that which would be achieved with more energy efficient equipment.

6.2 CONCLUSIONS ON ADOPTION OF ICT-BASED SOLUTIONS FOR MONITORING AND CONTROLLING ENERGY USE IN THE PUBLIC INSTITUTIONS

In the public institutions, there is a general lack of awareness on available ICT technologies that that can be adopted to monitor and control energy used by the various units and departments of these institutions.

The recently introduced pre-paid meters (Yaka) in the country have not yet been effectively deployed to individual departments, units or buildings in the public institutions. These meters would also be too cumbersome to install in each and every place where energy use has to be monitored, because they rely on wired connection.

There exist several ICT-based systems that can be adopted by the public institutions to measure and control energy use even up to individual socket level or individual room level. These technologies vary in cost depending on the number of users and the sizes of the buildings. They invariably rely on technologies such as WIFI, Bluetooth, the Internet, GPRS, GIS, etc.

Besides monitoring and controlling (ration, switch on/off) energy use, it is also important to have systems that inform users about the energy they use on a daily and periodic basis. This can enable the users to change their attitudes and behaviors in energy consumption as they become accountable and become aware of the impacts of their actions on energy consumption.

Besides energy monitoring and control systems, it is possible that the costs of energy could be reduced through adoption of alternatives to grid electricity, such as solar power, and energy saving devices.

6.3 CONCLUSIONS ON THE POTENTIAL BENEFITS AND COSTS OF ICT-BASED ENERGY MONITORING AND CONTROL SYSTEMS

In line with information from the respondents, it is conceivable that costs related to energy use can be reduced through introduction of systems that allow workers to monitor their energy use on an hourly, daily and weekly basis. The cost savings can arise out of reduced waste, less energy consumption and less administrative costs as each unity takes responsibility over its energy bills.

The costs involved in installing smart ICT enabled energy monitoring and control systems include cost of equipment, training costs, installation costs and operational costs to keep the systems running.

From the findings of this study, it is apparent that the overall benefits of adopting state-of-art ICT technologies for monitoring and controlling energy use in public institutions can significantly outweigh the costs and other challenges involved, especially in the long run.

7. RECOMMENDATIONS

The Ministry of Energy should step up efforts on improving energy end-use efficiency in public institutions. This can be done by requiring and supporting the institutions in energy efficiency campaigns aimed at changing attitudes and behaviors, as well as creating awareness of state-of-art energy monitoring and control systems that enable closer monitoring and control of energy use by the various departments or units in the institutions.

The Government should consider making subsidies on importation of energy monitoring and remote-control appliances and technologies. Government should also consider innovative ways of discouraging energy waste and careless consumption in the public institutions, e.g. budgetary limits, cost-sharing thresholds, etc. This calls for thorough further research on the true energy requirements of the various institutions before such limits can be imposed.

The ministry of ICT should promote innovations in development applications for monitoring and controlling energy use. This could include awards to individuals and groups with innovative concepts in this area. However, the promotion needs to go beyond perfunctory and ceremonial rewards, to include support transform the prototypes into actual products that are manufactured and marketed at an industrial scale. This calls for thorough research on the market potential of each sponsored innovation, and the linkages between the various institutions (production, finance, marketing, etc.) that could be involved in the process of developing the products.

The ICT and Energy ministries should jointly operate a databank on smart technologies for energy monitoring and control. This information should be availed to the public and institutions through publications and campaigns on promoting energy use efficiency.

Donors and government should promote research, training and awareness on efficient energy use. Government should require public institutions to produce an energy utilization audit indicating the breakdown of energy consumption requirements for each unit or department. These audits would provide information for several purposes such as budgetary allocations, planning, equipment replacement, and periodic performance and statistics on energy efficiency.

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