

The Future Contribution of Demand Side Management to Solving Kenya's Energy Insecurity Problems

E. Kiprop, K. Matsui, and N. Maundu

Abstract—With technological advancement, demand side management has become important part of energy conservation in developed countries. In developing countries, it can also contribute to alleviating energy supply insecurity, but so far only a few countries have adopted it. This paper attempts to understand how administrative personnel in Kenya's government agencies, including energy research institutions, perceived about the acceptability and accessibility of demand side management among the electricity consumers. We conducted the questionnaire survey among government officials, independent power producers and researchers to identify their perceptions about public awareness, willingness, and practice of adopting demand side management. Our questionnaire also attempted to clarify the viability and the impact of implementing various demand side management options. The results show that about 68% of the respondents believed that the public had low awareness. About 62% were still optimistic that the electricity consumers would adopt demand side management in the future. In terms of educating the consumers about the importance of this management, about 72% were rarely engaged. As to the extent to which our respondents found the viability of various demand side management options, the respondent emphasized the importance of price-responsive demand (81%), renewable energy adoption by households (74%), energy efficiency and conservation (64%) and integration of smart appliances (61%). About 48% of the respondents believed that the peak demand would be reduced by over 50% by implementing these options.

Index Terms—Demand side management, Kenya's energy sector, electricity consumers, energy experts.

I. INTRODUCTION

Past studies [1]–[3] have proposed ideas to solve energy insecurity that many developing countries have faced. These ideas range from energy generation capacity/storage improvement to demand side management. All these appear to have both positive and negative implications. Building new power plants, for example, can increase energy generation capacity but raise concerns about environmental issues. Large-scale storage technologies are still at development stages. Pumped hydro storage, despite its a mature large-scale technology, has geographical limitations [3].

Demand side management implies demand-side technologies, actions and programs that can reduce energy consumption and contribute to GHG emission reduction [4]. Previous researches on demand side management [1], [2], [4]–[6] emphasized its effectiveness in managing electricity consumption. Walawalkar [7] showed that demand side management could also be useful in solving energy challenges associated with the expected widespread adoption of intermittent renewable energy sources. On the other hand, Davito [1] noted that in the past demand side management had limited available technologies. Therefore, it focused only on industrial and commercial consumers while neglecting residential ones. However, the availability of smart grid and smart meters have recently allowed all consumers, including residential ones, to be involved. The US Federal Energy Regulatory Commission estimated that demand side management could potentially reduce as much as 150 GW in the 2019 peak energy period, compared to the business-as-usual scenario. As typical peaking power plant produces about 75 MW, this reduction is equivalent to the output of about 2,000 such power plants [8]. A similar study in the UK estimated that a potential reduction of 1.2–4.4 GW was achievable with existing demand side management options in the non-domestic sectors. Additionally, the UK Department of Trade and Industry (DTI) estimated that residents and small businesses can save up to 1 GW through demand management [9].

Despite these promising outcomes, Muratori [4] concluded that a local optimum solution of demand side management may not lead to global optimum. Therefore, a country specific research is needed to optimize the benefits of this method for each location. In addition, developing countries have not paid much attention to demand side management. In Kenya, for example, the government focuses on increasing generation capacity and interconnecting its grid with other Eastern Africa Power Pool (EAPP) countries [10]. These strategies have resulted in higher supply than demand capacity. For example, the 2018 peak demand was 75% of the installed capacity and that of 2021 was projected to be 43% [11], [12]. Although the installed capacity exceeds the peak demand, the country still experiences frequent power outages.

This paper argues that demand side management is one of the most viable options to alleviate power outages in Kenya. This, in turn, will contribute to Kenya's goal of supplying 100% energy from renewable sources. In this paper, we seek to address the following questions: how do government officials understand about the electricity consumer acceptance of this management? What are the most viable demand side management options for Kenya? Our previous

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study [9] on demand side management in Kenya focused on household energy consumers' perceptions. However, this paper examines perceptions of policymakers and implementers in Kenya to better identify challenges to formulating and implementing demand side management programs.

II. MATERIALS AND METHODS

A. Data Collection

As this study targeted energy policy formulation and implementation, we administered questionnaire to technical personnel at the Ministry of Energy and Petroleum, government agencies (Kenya Power and Lighting Company, Energy and Petroleum Regulatory Authority, Rural Electrification and Renewable Energy Corporation, Geothermal Development Corporation, Kenya Electricity Transmission Company, Ltd.), independent power producers, and academic institutions.

The methodologies of most [13]–[15] of the previous studies on demand side management have been based on modelling and simulation. Apart from being expensive, these methodologies does not put into consideration the human factors that are the main determinants of demand side management adoption by consumers. On the other hand, this study utilizes energy experts' first-hand experience and clear understanding of Kenya's energy sector. In addition, from their understanding of Kenyan electricity consumers, they can give a better prediction of their behavior if given an opportunity to adopt demand side management practices.

The questionnaire survey was administered between May and July 2019. Prior to this, a preliminary survey was conducted to make sure that the respondents could understand all the questions. The questionnaire was then administered to 31 personnel through purposive sampling.

The design of our questionnaire was formulated after reviewing studies on demand side management [1], [7]–[9], [16], [17], consumer perception and awareness on demand side management [2], [4], [18], [19], demand side management adoption [20]–[22], and peak demand reduction [14], [15], [23], [24]. In addition, we carried out an extensive review of government publications on Kenya's energy sector [10]–[12], [25].

The questionnaire was divided into five sections. The first section identified the socio-demographic characteristics of the respondents. The second section looked into the respondents' perceptions about public awareness and willingness to adopt demand side management. The third section investigated current demand side management practices. In the fourth section, we sought to understand the viability of various demand side management practices in Kenya. The fifth section investigated the extent to which the current peak demand would be reduced with demand side management implementation. The collected data were coded and entered into Microsoft Excel 2016. The data were analyzed by using Microsoft Excel Analysis ToolPak and summarized using both descriptive and inferential statistics.

III. RESULTS AND DISCUSSION

A. Socio-Demographic Characteristics

The first part of the questionnaire on socio-demographic characteristics identified age, gender, organization, work experience and educational level of the respondents. About 87% of the respondents were males. Regarding age, about 71% fell within an age bracket of 30-39 years old. The section on education qualification showed that only 3% of the respondents had diploma (middle level college) while about 55% had postgraduate degrees. About 58% of the respondents had 5 to 10 years of work experience and about 19% had more than 10 years. The respondents worked for government energy agencies (45%), the Ministry of Energy and Petroleum (39%). Others include, independent power producers (10%) and academic institutions (6%).

B. Level of Awareness and Willingness to Adopt Demand Side Management Practices

In the second section of the questionnaire, we asked their perceptions about public awareness of and willingness to adopt demand side management. First, we asked them to rate the level of consumers' awareness of the importance and availability of demand side management. We then asked them to rate consumers' willingness to adopt demand side management programs.

Regarding the level of awareness, about 68% of the respondents rated consumers' awareness as low or very low, 13% as average and 19% as high (Fig. 1). The low level of awareness could be attributable to the lack of consumer education and sensitization. Previous researches [6], [21] showed that awareness and knowledge precedes the adoption of demand side management.

Our multiple regression analysis found that organization (p -value=5.01E-05), experience (p -value=7.951E-03) and education (p -value=2.934E-02) significantly affected their perceptions about awareness of demand side management. Further analysis showed that most of the respondents at the Ministry of Energy and Petroleum (83%) tended to find public awareness low or very low. In addition, those respondents with 5 to 10 years (78%) of work experience rated likewise. On the contrary, all those respondents at academic institutions regarded the public awareness as high or very high. This shows a perception gap between academics and government officials.

On the second question, about 62% of the respondents rated consumers' willingness to adopt demand side management as very high or high, 19% as average, and 20% as low or very low. The reason for the high level of willingness to adopt demand side management could be attributable to the high utility cost Kenyan consumers' experience. Similarly, consumers in other countries [19], [26], [27] indicated that they would like to adopt demand side management for cost saving.

Our multiple regression analysis showed that respondents' age (p -value=4.510E-05), gender (p -value=2.016E-04), experience (p -value=1.021E-02) and education (p -value=1.837E-04) significantly affected their perceptions about willingness. Further analysis showed that those who rated the willingness as high or very high tended to be

between 20 and 29 years old (75%). All female respondents and most of those with less than 5 years of experience (72%) responded likewise.

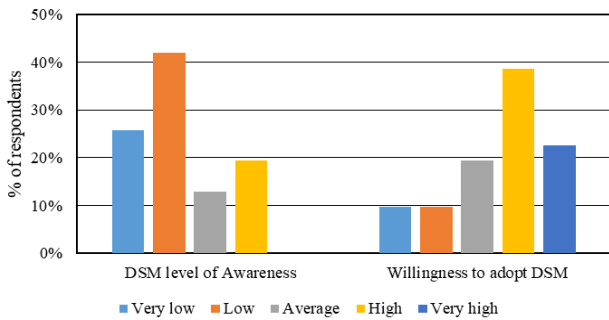


Fig. 1. Level of awareness and willingness to adopt demand side management (DSM) programs.

C. Education and Practices on Demand Side Management

In the third section of the questionnaire, we first asked the respondents how often consumers received education on demand side management by their respective organizations. We then asked them to what extent the consumers currently practiced demand side management.

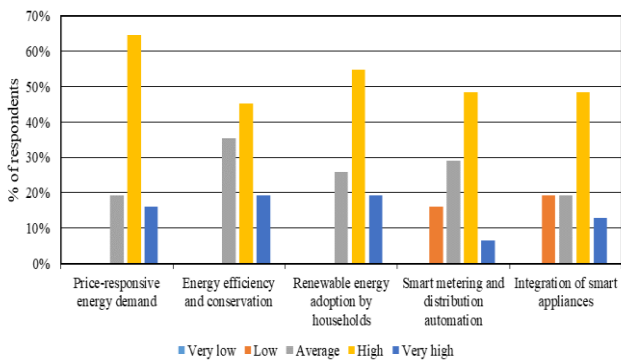


Fig. 2. Viable demand side management practices in Kenya.

Concerning the first question, about 72% of the respondents indicated that they rarely educated consumers while the rest indicated that they educated quarterly. Similar studies in the US, Korea and other countries [1], [13], [21], [26], [27] emphasized the importance of consumer education.

Our regression analysis indicated that age (p -value=5.359E-03), organization (p -value=4.866E-05), experience (p -value=5.77E-03) and education (p -value=1.011E-04) affected their perceptions about information dissemination. Those who rarely informed consumers belonged to age groups of 30-39 years old (77%). They were also working for academic institutions. Those with 5-10 years of experience (89%) and those with bachelor's degree (77%) fit into this category. This suggests that consumer education is done mainly by the Kenya Power and Lighting Company or the Ministry of Energy and Petroleum.

As for the second question, about 29% of the respondents considered consumers to practice demand side management sometimes, about 35% rarely, 19% not at all. Presently only a small number of consumers have installed smart meters while those in the rural areas have installed solar PV as a way of reducing their power demand [28]. Previous researches from

other countries [20]-[22] attributed the low adoption rates of demand side management to the lack of infrastructure and the skepticism among electricity consumers.

Our regression analysis indicated that age (p -value=2.316E-03), gender (p -value=1.012E-03), and experience (p -value=1.343E-02) affected their perceptions on consumers' current practices. All the respondents above 40 years old and all the female believed that the public rarely use demand side management. Those with more than 10 years of work experience also indicated so.

D. The Viability of Various Demand Side Management Practices

In the fourth section, we sought to find out the viability of various demand side management options. We asked the respondents to rate the viability of these options. The results showed that price-responsive demand (81%), renewable energy adoption by households (74%), energy efficiency and conservation (64%), and integration of smart appliances (61%) were the most viable (Fig. 2). Smart meters and distribution automation (54%) ranked the lowest.

Basically, the purpose of price-responsive energy demand is to entice consumers to shift their power demand to a time period when the generation cost is lower [9]. This corresponds with findings of some previous researches in the US and Europe [1], [29]. In the US, for example, a peak demand reduction of 5% could reduce the demand for peaking generation by 50% [30]. In Kenya, the peak demand is about 12% of installed capacity [9], [11]. This demand capacity can be reduced significantly if consumers monitor real time prices and shift their demand to off peak hours.

Our regression analysis found the notable connection between the responses on price-responsive energy demand with gender (p -value=1.807E-03) and education (p -value=3.559E-02). Most of the male respondents (89%) and those with postgraduate degree (95%) tended to rate high or very high.

About 74% of the respondents found household renewable energy adoption viable as Kenya has a high potential for solar PV generation [31]. As the household sector is the fastest growing energy consumer base, the cost of solar PV and small-scale storage has been significantly reduced [9]. A previous survey on Kenya's electricity consumers indicated that 84% wanted to adopt renewable energy sources [28]. Here our regression analysis found significant connection between the viability of household renewable energy adoption and respondents' age (p -value=2.346E-03), education (p -value=3.080E-06) and experience (p -value=4.471E-04). Those who responded high or very high were within the age bracket of 30-39 years old (69%). Also, most of those with bachelor's degree (85%) and those with more than 10 years of work experience (83%) fell into this category.

Another highly viable option the respondents selected was energy efficiency and conservation. Kenya has recently improved energy efficiency. For instance, in 2009 and 2012, the government, implemented the first and second phases respectively of efficient lighting programs for residential areas, distributing 4.8 million compact fluorescent lamps (CFLs). The programs resulted into a peak demand reduction

of 178 MW (11% of 2012 installed capacity) [9].

Here our multiple regression analysis found the significant connection between energy efficiency/conservation and respondents' gender (p -value=2.353E-02) and education (p -value=2.470E-02). The majority of male respondents (74%) and those with postgraduate degrees (95%) indicated high or very high.

As for the integration of smart appliances, although the respondents found important, our multiple regression analysis showed no significant relationship between the viability of integrating smart appliances and the respondents' socio-demographic characteristics.

Although smart metering and distribution automation ranked the lowest, our multiple regression analysis found the significant connection between this option and respondents' organization (p -value=1.683E-02). Kenya has started installing smart meters and adopting grid modernization [10], [12].

E. Impact of Demand Side Management Implementation on Peak Demand

In the fifth section, we investigated the extent to which the current peak demand would be reduced with demand side management. We asked the respondents about the extent to which the peak demand would be reduced by demand side management implementation.

In response, about 48% of the respondents indicated that the peak demand would be reduced by more than 50%. Another 23% said that it would be reduced by 40 to 49% (Fig. 3). This result corresponds with the findings of the studies in the US, Italy, and UK [1], [14], [15], [23], [24].

Here our multiple regression analysis found the significant connection between the impact of demand side management implementation and respondents' age (p -value=2.942E-05), gender (p -value=1.86E-05), experience (p -value=4.848E-04) and education (p -value=5.85E-08). Those who were 20 to 39 years old (76%) and female (75%) respondents tended to believe the reduction rate to be more than 40%. Those with postgraduate degrees (84%) and with less than 10 years of work experience (78%) indicated the same.

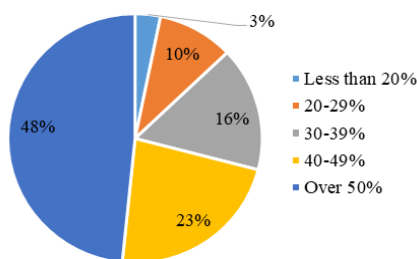


Fig. 3. The impact of full demand side management implementation on peak demand.

IV. CONCLUSION

This paper examined perceptions of policymakers and implementers about Kenya's electricity consumers' awareness, willingness, and practices concerning demand side energy consumption management. We also investigated the viability and the impact of implementing various demand side management practices. We found that about 67% of the respondents, mostly working for the Ministry of Energy and

Petroleum, considered consumers' awareness level as low. However, about 62% were hopeful that consumers were willing to adopt demand side management. Our respondents believed that price responsive demand (81%), renewable energy adoption by households (74%), energy efficiency and conservation (64%) and integration of smart appliances (61%) were the most viable options in Kenya. Most of the respondents with postgraduate degrees perceived price responsive demand as the most viable option. By implementing some of these demand side management practices, about 48% of the respondents, mostly with postgraduate degrees, said that the peak demand would be reduced by over 50%. Another salient finding is a gap in opinion between researchers and government officials. Those respondents who worked for research institutions perceived the high level of consumer awareness of demand side management, but those at government ministries perceived otherwise. While this paper showed that the Kenyan consumers' willingness to adopt demand side management is high, the determination that this would translate to actual high adoption rate is beyond the scope of the current research.

CONFLICT OF INTEREST

"The authors declare no conflict of interest".

AUTHOR CONTRIBUTIONS

Conceptualization, design of questionnaire, visualization, methodology, formal data analysis, writing—original draft preparation, E. Kiprop; questionnaire review and revision, writing—review, revision and editing, supervision, project administration, K. Matsui; data collection, writing – review and editing, N. Maundu. E. Kiprop served as the corresponding author. All the authors read and approved the final manuscript.

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