31 User Perceptions of and Needs for Smart Home Technology in South Africa

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Abstract

Homeowners are often frustrated in trying to understand and control the use of energy within the home especially in tracking monthly usage and the impact of a change in habit on their bills. Recent advances in computing power and sensing technologies required to implement a smart home energy management system mean small, low price and sustainable devices are available for wider adoption. But how ready are homeowners to allow these devices into their homes to collect personal data? This study attempted to understand users' perceptions and requirements of smart home systems in order that these may be more readily integrated into new and existing homes. A quantitative approach using self-administered questionnaires was distributed to a random selection of respondents falling within the sample population of households who have access to the internet at home within the Republic of South Africa. Conclusions are that homeowners need to be aware that if they do not implement smart home technology to improve their home management, they will in all likelihood end up paying more or even facing resource shortages due to the inefficiencies of the current methodologies used for managing their homes.

Keywords

Internet of things • Smart home • Sustainability • Energy management

31.1 Introduction

In the world we live in, we are constantly battling to achieve a manageable work-life balance, find time for social interaction alongside attainment of financial as well as environmental sustainability, requiring us to squeeze evermore into our congested days. Homeowners are often frustrated in tracking monthly usage or in trying to control the use of energy within the home, especially the impact a change in habit is having on their bills. Having to 'manage' energy efficiency in our homes or businesses, using time-consuming manual systems and requiring a facilities management 'degree', has led to much interest and media attention placed on the potential for smart building technologies to play a decisive role in achieving this in a more efficient manner.

The recent introduction of off the shelf solutions into the South African consumer market by major technology companies has provided an opportunity for a range of smart home devices to interact with one another to create a smart home environment. As revealed in a study by the South African Department of Energy [1], South African households spend upward of 14% of their total monthly household income on energy needs. When compared with the international average of

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10%, it means consumers are constantly seeking options to reduce their energy consumption, providing opportunity for technological solutions within an African environment.

According to Madakam et al. [2], smart home technology is the future of home energy management, allowing homeowners the opportunity to be completely in control of their own homes, as smart home devices will possess an Internet of Things (IoT) protocol to communicate their status to the homeowner in a real-time accessible manner, allowing informed management decisions. Taking into considerations some of the additional challenges in the African energy sector including rolling power outages and fluctuations in power, the ability to be able to control in particular the technology reliant on that energy, provides an added incentive to consider the use of these devices.

The aim of the study was to determine homeowners' perceptions of and needs for smart home technology in order to manage and monitor a home more efficiently and sustainably. The objectives were to determine why homeowners struggle to monitor energy/resource consumption; whether homeowners would use smart home technologies to do this; if this would have an impact on the homeowner's awareness of energy consumption, and if there were any potential monetary savings a homeowner may achieve using smart home technology.

31.2 Background

The home is a very personal and vulnerable space and it is therefore imperative that smart home system providers understand users' perceptions towards the technology to ensure greater acceptance and implementation of the technology. That need is very real, in South Africa due to a more than 300% increase in the price of electricity in the past decade [1]. The strategy employed by almost half of South Africans to cope with the rising electricity costs was to reduce the amount of electricity used, which can be further facilitated and expedited through the implementation of smart home technology to assist with the identification and monitoring of energy consumption within the home.

31.2.1 Energy Consumption Monitoring

Using existing metering technology, homeowners are only able to view their monthly consumption rate and kilowatt-hour charges by recording this visually or from their utility bill. Using this method homeowners are unable to gain real-time data of their consumption, individual appliance consumption and 'live' monthly consumption patterns. Froehlich et al. [3] believe that through disaggregated energy consumption data, detailed information of all home appliances in real-time can be provided by a smart home system to homeowners to better monitor their peak energy consumption and consumption patterns. Homeowners with this data clearly accessible will proactively improve their energy efficiency strategies and consumption patterns, ultimately reducing their overall energy consumption [4].

31.2.2 Energy Consumption Awareness

According to Abdelmohsen et al. [5] household electricity meters appear confusing to homeowners as the meter provides a reading of the electrical energy consumption of the home with the use of a moving dial. For a homeowner to determine their daily electrical energy consumption they would have to, without fail, read and record the electricity meter at the same time each day and manually calculate and compare the electrical energy usage [5].

The results of a study conducted by Brounen et al. [6] in the Netherlands indicated that energy awareness among homeowners was low, as just 56% of the respondents were aware of their monthly energy consumption usage and cost. A study conducted by Rihar et al. [7] found evidence that those homeowners who take note of energy efficiency and conservation, realise the opportunity a smart home system presents to achieve additional savings from efficient energy consumption in their homes.

31.2.3 Energy Inefficiencies in Current Homes

Meyers et al. [8] revealed evidence that a substantial amount of energy consumption within a home delivers amenities and comfort to occupants in an inefficient manner. A summary of energy wasted in the five identified categories of inefficient delivery and conversion of amenities is illustrated below in Table 31.1.

Table 31.1 indicates that 39.7% of primary residential energy use in the home is wasted, due to inefficient delivery and conversion of energy. This is because the climate in unoccupied homes or rooms is not controlled, continuing to feed switched-off appliances, and not varying energy supply with the changing needs of occupants over the course of the day [8]. Similarly, Williams et al. [9] observed that an estimated 41% of energy consumption is wasted based on the same factors.

This is in addition to energy loss from the likes of hot water storage devices, influenced by the lack of control of energy use. This is due to no attempt being made to regulate the flow of electric current to the heater, other than by the thermostat, meaning the water contained within the heater remains at or near the “set” temperature 24 hours a day regardless of the use of Zero, Small, or large Volumes of water [10].

Automatically determining when to turn on/off the electric current to such heaters, to reduce the expenditure for electricity without compromising the users requirement for hot water, can produce savings of between 12 and 14% in energy use [11, 12].

31.2.4 Knowledge as a Barrier for Better Home Management Through Technology

According to Scott [13], homeowners were not demanding smart features before 2007, whilst residential property developers had no concern for the sustainable performance of a home once it sold, therefore negatively affecting the possibility of installing energy management smart systems in new homes? In a survey in 2007 among home building contractors observing the potential market for smart homes, the majority of participants felt that smart home technology would remain a niche system focused on upmarket homes [13].

Meyers et al. [8] identified a lack of knowledge about energy management among homeowners in a study conducted in 2010, especially as payback times from energy savings are measured in months or years. This is difficult for homeowners to comprehend and does not always provide a compelling reason to invest a large amount of money initially. Energy conservation for most remained a mental challenge and often thought of as being too expensive for the minimal reduction in energy consumption [8]. They also identified a lack of knowledge among professionals on the associated costs and benefits of different kinds of Home Energy Management Systems (HEMS). In addition, there was a lack of compelling datasets informing professionals as to which system is most effective and sustainable from an energy and cost perspective.

In a South African study conducted by Nel et al. [14] participants encountered difficulty understanding their geyser’s energy consumption. Additionally, nearly 30% of participants are unsure of the potential energy and cost savings that can be realised through the switching on and off intermittently of their geyser [14]. Ford et al. [15] suggest that the full potential of smart home technology systems is limited by the conflicting information provided by professionals relating to energy consumption savings and the value proposition aligned to that.

Table 31.1 Energy wasted in inefficient delivery and conversion in homes

Factor	Base case % wasted (%)
Unoccupied homes	4.2
Unoccupied rooms	16
Thermostat oversetting	2.5
Leakage current	3
Appliance choice	14
Total	39.7

Adapted from [8]

31.2.5 Energy Savings from Smart Home Technology

According to Rihar et al. [7], implementing energy conservation specific smart home technology, as part of a HEMS, will enable homeowners to achieve substantial energy savings. Williams and Matthews [9] project, based on their research within the smart home technology field, that energy savings are positively correlated to the degree of connectivity within the smart home technology system. Ford et al. [15] consider that evidence for energy savings associated with the HEMS capabilities of smart home technology systems as ever increasing.

31.2.6 Privacy and Security Concerns Relating to Smart Homes

Horne et al. [16] suggest that if energy usage information and data is analysed to reveal personal details of a homeowner or occupants home life, which can be sold on to third parties, or if energy utility organisations are capable of controlling appliances within the home remotely, anti-smart home technology perceptions and advocacy may increase among the public, negatively impacting the adoption of these smart home technologies within the home.

The perceived difficulty in achieving security within home network environments has been identified by Jacobsson et al. [17] as one of the top barriers in preventing the adoption and implementation of smart home technology systems. This underlines that privacy and security is an important element in the successful adoption of smart home technology by homeowners. Jacobsson et al. [17] suggest the need for the integration of security in the design phase of smart home technology system development processes, using a model for security and privacy in design.

31.3 Methodology

The researchers employed a quantitative research method to gather data from homeowners, using self-administered questionnaires distributed to a random selection of the sample population identified from the 1.6 million (9.5%) households who have access to the internet at home, a subset of the 16.7 million households within the Republic of South Africa [18]. The sample size identified was statistically calculated by establishing a confidence level of 90% and a desired margin of error of six, which resulted in a sample size required of 200 respondents out of the sample population of 1.6 million. A random selection method was employed to ensure each respondent in the population was not chosen in predetermined manner to avoid the skewing of the findings and to eliminative any bias in the choice of respondents for the study.

The research questionnaire was distributed via e-mail to 200 respondents, of which 136 usable responses were received, a response rate of 68%. The questionnaire consisted of eighteen questions, five of which were demographics related; twelve were five-point Likert scale questions, whilst the last question was open-ended, allowing respondents to provide general comments that were not addressed previously.

The analysis of the data consisted of the calculation of descriptive statistics in the form of frequency distributions and a measure of central tendency, based upon the percentage responses to the points on the respective scales. This enabled interpretation of the responses and to rank factors where necessary, in order to calculate mean scores (MSs). For this study, the Likert scale points form a scale that ranges from one to five, 1 being not important to 5 very important, in order to calculate the mean scores.

31.4 Findings

Of the 136 respondents, 83% of respondents have owned or rented a residence for more than 5 years and 69.8% in excess of 10 years, with nearly 90% (89.7%) owning or renting a freestanding house. Respondents were then asked to indicate the extent to which an existing home’s appliances have an impact on the use of the home based on a scale of 1 (minor) to 5 (major), with the results tabulated in Table 31.2.

It is notable that 10 out of the 12 questions (83.3%) had mean scores greater than 3.00. Time saving ranked first based on a resultant mean score (MS) of 3.76, with Ease of use (MS3.71) following closely behind. Living environment, Safety and security and Life satisfaction were perceived to have between some extent to a near major extent a positive impact on the use of the home.

Table 31.2 How existing home's appliances impact the use of the home

Factor	U	Response (%)					MS	Rank
		Minor	…			Major		
		1	2	3	4	5		
Time saving	2.2	2.2	8.8	24.3	37.5	25.0	3.76	1
Ease of use	2.2	2.2	3.7	31.6	42.6	17.6	3.71	2
Living environment	4.4	2.9	2.9	33.8	39.0	16.9	3.67	3
Safety and security	2.2	8.8	9.6	21.3	28.7	29.4	3.62	4
Life satisfaction	5.9	5.1	10.3	28.7	33.1	16.9	3.49	5
Happiness	4.4	5.9	14.0	29.4	36.0	10.3	3.32	6
Resource usage	9.6	5.9	11.9	34.1	25.9	12.6	3.30	7
Monetary expenses	2.9	8.1	11.8	33.8	33.1	10.3	3.27	8
Socialisation	3.7	9.6	15.4	26.5	33.8	11.0	3.22	9
Personal health	4.4	13.2	14.0	33.8	25.7	8.8	3.03	10
Emotions	9.6	13.2	16.9	33.8	22.8	3.7	2.85	11
Natural environment	14.0	13.2	19.1	31.6	14.7	7.4	2.81	12

Table 31.3 The extent to which being able to connect with a home's appliances through a connected smart home system will impact on the use of the home

Factor	U	Response (%)					MS	Rank
		Minor	…			Major		
		1	2	3	4	5		
Time saving	8.1	2.2	2.9	14.0	33.8	39.0	4.14	1
Safety and security	7.4	5.9	6.6	17.6	29.4	33.1	3.83	2
Ease of use	10.3	7.4	5.9	18.4	32.4	25.7	3.70	3
Living environment	12.5	6.6	8.1	23.5	33.8	15.4	3.50	4
Resource usage	14.0	7.4	8.8	25.7	27.9	16.2	3.43	5
Life satisfaction	9.6	6.6	11.0	24.3	35.3	13.2	3.41	6
Monetary expenses	14.0	8.8	8.8	22.8	30.1	15.4	3.40	7
Happiness	12.5	9.6	8.8	31.6	26.5	11.0	3.24	8
Socialisation	8.8	14.0	12.5	27.2	25.7	11.8	3.10	9
Emotions	14.0	11.0	9.6	36.8	21.3	7.4	3.05	10
Natural environment	22.8	12.5	11.8	23.5	22.8	6.6	2.99	11
Personal health	15.4	13.2	14.0	26.5	24.3	6.6	2.97	12

Respondents were then required to indicate the extent to which being able to connect with a home's appliance through a smart home system will impact on the use of the home based on a scale of 1 (minor) to 5 (major), with the results tabulated in Table 31.3.

It is notable that a similar ratio of MSs > 3.00 was achieved 10/12 (83.3%) from the respondents and that 'Time saving' is also ranked first, but with a much increased MS of 4.14. This indicates that time saving is perceived to be impacted the most by being able to connect with a home's appliances through a connected smart home system.

In terms of the impact being able to connect with a home's appliances through a smart home system will have on quality of life in general, the resultant MS is lower at 3.57 which is somewhat surprising given the previous upward tick in the MS's when looking at the factors aligned to being able to connect with a home's appliances through a connected smart home system and its impact on the use of the home.

With respect to the importance of having remote access to a home on optimising the operational efficiency of a home, the resultant MS of 3.72 is also within the same range.

Respondents were then asked to 'rate the accessibility of your current method to review consumption values of your home's equipment?', with the results tabulated in Table 31.4.

This was then followed by a question that addressed the impact of being able to better manage the consumption in a home by being able to communicate with one's home's equipment as well as between each piece of equipment through a connected smart home system, with the results tabulated in Table 31.5.

It is notable that 'Electricity' ranked first in both questions which indicates that electricity is perceived, on the ability to better manage the consumption in a home, to be impacted the most as a result of being able to communicate with a home's equipment as well as between each, through a connected smart home system.

Respondents were required to indicate their extent of current understanding of the resource consumption of a home. The resultant MS of 3.22 is in the 2.60 to ≤ 3.40 range, indicating that respondents deemed their current understanding to be between a near minor extent to some extent.

Respondents were required to indicate how frequently they monitor the consumption in their home currently (Table 31.6).

This question was followed with respondents indicating how frequently they would monitor the consumption in their home if it was readily available on a connected smart home system (Table 31.7).

Table 31.4 Accessibility of current methods' to a home's equipment consumption values

Resource	U or N/A	Response (%)					MS	Rank
		Not	…			Very		
		1	2	3	4	5		
Electricity	8.8	5.9	9.6	30.9	27.2	17.6	3.45	1
Water	10.3	10.3	12.5	27.9	19.9	19.1	3.28	2
Gas	30.9	11.0	11.0	24.3	14.0	8.8	2.98	3

Table 31.5 The impact of the ability to communicate with a home's equipment and between devices through a connected smart home system, to better manage the consumption in a home

Resource	U or N/A	Response (%)					MS	Rank
		Minor	…			Major		
		1	2	3	4	5		
Electricity	11.8	8.1	5.9	14.7	34.6	25.0	3.71	1
Water	16.2	12.5	5.1	19.1	27.2	19.9	3.44	2
Gas	33.8	8.1	5.9	21.3	17.6	13.2	3.33	3

Table 31.6 The frequency of monitoring the consumption in a home

Resource	U or N/A	Response (%)					MS	Rank
		Minor	…			Major		
		1	2	3	4	5		
Electricity	2.2	5.1	12.5	14.7	36.8	28.7	3.73	1
Water	4.4	12.5	16.9	20.6	24.3	21.3	3.26	2
Gas	27.9	13.2	14.7	16.9	14.7	12.5	2.98	3

Table 31.7 The frequency of monitoring the consumption in a home if it was readily available on a connected smart home system

Resource	U or N/A	Response (%)					MS	Rank
		Minor	…			Major		
		1	2	3	4	5		
Electricity	1.5	2.2	2.2	10.3	28.7	55.1	4.34	1
Water	2.2	3.7	2.2	9.6	30.9	51.5	4.27	2
Gas	22.8	2.9	4.4	8.8	20.6	40.4	4.18	3

It is notable that all 3 resource consumption monitoring frequencies (100%) had improved mean scores greater than 4.00.

With respect to the extent of improving understanding of resource consumption on the ability to use technology to manage a home through a connected smart home system. The resultant MS of 4.06 is also within the >3.40 to ≤ 4.20 range, which indicates that the respondents perceive it to be between some extent to a near major extent.

Finally, respondents had to indicate to what extent improving on their understanding of a connected smart home system would have on their ability to use technology to manage their home. The resultant MS of 4.07 falls within the same range, that this would between some extent to a near major extent improve on their ability to manage their home.

31.5 Conclusions and Recommendations

31.5.1 Conclusions

The research set out to understand South African users' perceptions and requirements of smart home systems, and the improvement of a homeowner's ability to manage and monitor a home more efficiently and sustainably through smart home technology. The respondent's perceptions are that smart home technology increases a homeowner's awareness of energy consumption and improves access to monitoring that consumption compared to existing methods, although knowledge of smart home technology is currently extremely limited among homeowners. Homeowners are willing to implement smart home technology if the implementation is seamless and not cumbersome for themselves and were willing to learn more about the technology. Where they had better access to resource consumption data it lead to lower consumption usage. Respondents were of the belief that smart home technology leads to an increase in quality of life for homeowners, however, in the South African market it has been concluded that cost and privacy are a barrier to implementing smart home technology in their homes.

There is a perceived negative sentiment among existing homeowners to the use of new technology within the management of a home and, in addition, that the monitoring process using smart home technology may expose too much information, seem complex to the user. However, homeowners need to be aware that if they do not implement smart home technology to improve their home management, they will in all likelihood end up paying for the inefficiencies of the current methodologies used for managing their homes.

31.5.2 Recommendations

Communicating to homeowners the total capital outlay versus monetary savings on energy conservation over lifetime of the system; Addressing privacy concerns and the security of the data captured; Focusing on time saving, life satisfaction, security and improvement in the living environment leading towards a better quality of life; increasing education and training, particularly the lack of energy consumption awareness; whilst addressing the ease of use/complexity of system challenge, are some of the areas that need to be addressed by the industry if they are to see greater uptake of these systems within the South African home building and refurbishment market.

Based upon the findings of the study and the conclusions that have been drawn, the following recommendations are thus proposed: Industry professionals need to educate homeowners on the multiple benefits of smart home technology; They need to investigate the specific needs in relation to cost that property owners are prepared to pay for when it comes to smart technology in the home; Professionals need to educate the wider population to create an awareness of smart home technology and in particular the energy consumption and monitoring type of smart home technology with inter alia safety and lifestyle support. Further education and training on resource consumption through smart home technology should be implemented in conjunction with the installation of smart home technology. Customisable smart home technology systems should be preferred over off the shelf systems to ensure the most sustainable outcome is achieved for the homeowner, with attention paid to a phased approach to installation starting with utility smart meters. This study contributed to the South African body of knowledge by understanding current perceptions within the homeowners' market towards these devices as well as overall knowledge of smart home technology, however, case study is needed to analyse whether users experience of smart home technology aligns with the perceptions of those surveyed towards the use of the technology.

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