

# An IoT based Home Automation Integrated Approach: Impact on Society in Sustainable Development Perspective

Yasir Mahmood\*<sup>1</sup>

Advanced Informatics Department, Razak Faculty of  
Technology and Informatics, Universiti Teknologi  
Malaysia, 54100, Kuala Lumpur, Malaysia  
Department of Software Engineering, Faculty of  
Information Technolgy, The University of Lahore  
Lahore, Pakistan

Nazri Kama<sup>2</sup>, Azri Azmi<sup>3</sup>, Suraya Ya'acob<sup>4</sup>

Advanced Informatics Department  
Razak Faculty of Technology and Informatics  
Universiti Teknologi Malaysia, 54100  
Kuala Lumpur, Malaysia

**Abstract**—In recent years, due to substantial evolution in the field of consumer electronics, the society is striving to optimize efficiency, energy savings, green technology and environmental sustainability in their daily lives at homes. Most of the people are controlling and monitoring home appliances manually and therefore, facing lots of problems in managing natural resources, cost, effort and security which lead towards an un-comfortable and un-reliable life. Numerous 'intelligent' devices such as smartphones, tablets, air-conditioners, etc. have promoted the key concept of the Internet of Things (IoT) based home automation. Entrenched with technology, these devices can be distantly monitored and controlled over the Internet at home and anywhere in the world. Over the past few decades, global warming has become a severe worldwide challenge. However, sustainable development and green technology play an important role in climate change. The primary purpose of this study is to save natural resources, reduce energy consumption, and to understand the impact of home automation on the society in order to achieve the goal of green technology and environmental sustainability. In this paper, IoT based home automation approach integrated with the smart meter, solar, wind, geothermal renewable energy resources and government green awareness program to extensively optimize the need of energy consumption, security, cost, convenience and cleaner environment for the society is proposed. In addition, a survey was conducted among the target audience for the purpose of identifying and evaluating its least impact on the environment and society in a sustainable development perspective. The results of this survey are statistically analyzed using IBM SPSS statistics version 23. The results revealed that there is a significant impact of home automation on the society thereby contributing to its solution.

**Keywords**—Internet of Things; smart home; sustainable development; home automation; environment sustainability

## I. INTRODUCTION

Recent years have witnessed rapid advancements in the Industrial Revolution (4IR) enabling technologies as a chunk of the Internet of Things (IoT) for home automation. The fast-growing thought of Internet of Things (IoT) is used to achieve the goal of highest environmental friendly and green standards of sustainability in order to monitor the home appliances and

energy conservation at home environment. The users are gradually offered numerous adapted services like home automation, security, controlling and monitoring, entertainment, healthcare etc. In particular, many home automation research projects have been developed for old and handicapped people to prolong their stay at home for independent living and assisting them in their everyday life [1]. Home automation technology provides security, comfort, power saving, efficiency, go-green technology and environmental sustainability by enabling intercommunication amongst all household appliances through smartphones or other networked devices anywhere in the world. Besides, the home appliances, healthcare and security are the vital features which can be controlled and operated remotely by programs or remote platforms. The usage of smart meters can bring significant impact on home automation systems through which accurate meter readings can be achieved successfully. The smart meter readings can be transferred automatically to the utility companies in order to optimize efficiency. The consumption of home water, electricity, gas, and telecommunications can be monitored and controlled over time. In recent years, smart homes are progressively getting cost-effective and efficient with continued progress in the fast-growing field of IoT technology which links the internet with physical objects globally. Due to the progressive utilization of IoT, a large number of applications have been developed in the domain of transportation, home, building, city automation and healthcare [2]. The IoT has the greatest potential to lower down the environmental load significantly on the society and the users should adopt such technologies which can help them to develop energy efficient buildings and homes. The IoT encourages building constructors and industries in developing more energy efficient buildings and to achieve green home key components like sustainable location, water, energy consumption and indoor environmental quality.

Globally, it is investigated that buildings and homes are consuming approximately 40% annual energy consumption of the total world. This energy is specifically utilized for lighting, heating and cooling systems in building and homes. Some vital steps need to be taken through green awareness strategies of the environmental impact on society using advanced

\*Corresponding Author

technologies. Therefore, it is required to investigate reducing the rate of energy consumption and environmental pollution for a cleaner and greener society. One of the ways of reducing energy consumption and environmental sustainability is to automate buildings and homes while achieving good indoor environmental quality life [3].

In this paper cost-effective, a comfortable and reliable environment is created with IoT based home automation technique. Besides, smart meter, solar, wind and geothermal renewable energy resources, and green awareness program are integrated with home automation to minimize demand of energy, optimize the demand response and to achieve the goal of green technology and environmental sustainability for the society. Moreover, a survey is conducted to identify the least impact of home automation approach on the environment and therefore to society.

#### A. Motivation

Nowadays, society is facing lots of problems in managing their home appliances and energy consumption in terms of affordability, efficiency, effort, reliability and therefore spending uncomfortable and inconvenience life. Furthermore, the chances of robbery and thefts are getting common in the society, hence needs to put serious attention by taking few measures into consideration to ensure the safety of every individual by keeping it as an important element in daily lives. In order to overcome these concerns, the Internet of Things (IoT) plays a significant role for home automation which connects various objects like cellular phones, computers, appliances, for the intent of interaction with each other and an entire world. The main motivation of this paper is to promote green technology and environmental sustainability by developing a smart home using IoT so that Go Green environment can be achieved successfully. We focus our consideration on smart home and study the latest developments in functioning principle of diverse type of wireless communication techniques such as voice recognition, ZigBee, Wi-Fi (IoT based home automation) Bluetooth, and GSM enables energy consumption, green technology and environmental sustainability. Eventually, an integrated home automation conceptual approach is proposed to save natural resources, reduce power consumption and environmental impacts to achieve the goal of green technology and environmental sustainability for the society.

#### B. Research Contribution

The main contributions of this paper are as below:

RC-1 An integrated home automation conceptual approach is proposed in which smart meter, solar, wind and geothermal renewable energy resources and green awareness program are combined to improve householders' convenience, comfortability, cost, effort, security and to reduce environmental impacts to achieve the goal of green technology and environmental sustainability for the society.

RC-2 A relationship is established between 4IR enabling technologies-Internet of Things (IoT), home automation and renewable energy resources to optimize green technology, energy consumption and environmental sustainability.

RC-3 A comprehensive survey is conducted to validate the impact of an anticipated solution on the society in sustainable development perspectives.

#### C. Organization

This paper is structured as follows. Section 2 describes a related work to identify gaps in the research area. Section 3 briefly presents a research methodology. An integrated home automation conceptual approach and its architecture described in Section 4. Section 5 explains the impact of the proposed approach on the society. In Section 6 the data analysis and results are discussed. Section 7 presents the conclusion and future research direction.

## II. RELATED WORK

The basic idea behind IoT is to make everything around us accessible for monitoring, controlling and communicating over the internet anywhere in the world. However, in order to make a sustainable automation world, all devices should be furnished with sensors, communication tools and techniques so that the users can communicate with the devices globally [4]. Due to substantial energy loads, high costs and limitations on natural resources have upraised the concerns about resource preservation. Researchers are required to investigate buildings and homes power management techniques for energy consumption and conservation. Green IoT emphasizes the smart world with environmental sustainability by reducing energy consumption. A lot of applications [5]-[7] exist related to IoT out of which some are as follows.

**Smart Home:** With a smart home, the appliances are controlled and monitored by making lifestyle convenient and comfortable. The home devices can remotely communicate and interact with each other.

**Industrial Automation:** The manufacturing machines are automated therefore helps in finishing their tasks with minimal human involvement. The automated machines are controlled and monitored robotically with an increase in productivity ratio.

**Smart Healthcare:** The sensors and actuators are embedded in patients for tracking, controlling and monitoring the health conditions of patients, hence enhanced healthcare performance and efficiency.

**Smart Grid:** Power grid stations are controlled and managed to ensure a continuous supply of energy to the people. Therefore, energy consumption could be enhanced.

Growing issues on global warming, energy consumption and costs have put a great responsibility on researchers for exploring new ways to overcome these concerns. One of the ways is to engage and helping people in climate-friendly behaviours. According to [8], lots of efforts are required to put in on energy consumption on home sectors in particular. For instance, to increase awareness of energy conservation at the workplace and home and to assist people for water, gas and power consumption at different places. Some researchers have proposed home techniques that control and monitor energy consumption and also investigated how residents use home energy tutor system [9]. Few researchers have developed

gaming interfaces user-friendly automated application for energy conservation [10].

Information and Communications Technology (ICT) plays a key role in a sustainable environment for the future which is getting one of the most serious challenges of the 21<sup>st</sup>-century era. The main goal of ICT is to save energy in order to accomplish effective environmental protection for numerous areas including housing, manufacturing, buildings, power consumption, power grid stations, etc. As a result, it is important to highlight that the saving of energy is required where there are wired and wireless network platforms [11]. Therefore, there is a critical need for major research [12] on the reduction of energy use in different types of networks and cellular devices. The green wireless communication technologies [13] help in reducing the impact on the environment.

In recent years, wireless communication technologies are gaining popularity for the use of smartphones which are able to control and monitor the home appliances remotely anywhere in the world. Various home automation systems are using this technology including Bluetooth, Voice Recognition, ZigBee, GSM and Wi-Fi (IoT based). Bluetooth based home automation system is proposed by [14]. The proposed system consists of an Arduino board and a cellular phone which communicate through wireless Bluetooth technology. In this proposed system, the Arduino board is used to connect home appliances through a relay. A Software application is also being developed which permits users for controlling home appliances. The home automation system based on voice recognition is proposed by [15]. The hardware architecture of this system comprises of Arduino UNO and a smartphone. The wireless communication is done via Bluetooth technology. The home appliances can be controlled through the user's voice commands due to built-in voice recognition feature capability of Android smartphone. The working mechanism of this system is that it first converts the voice commands into text messages and then transmits to the Bluetooth module. This module HC-05 is connected with Arduino UNO. ZigBee Based Wireless Home Automation System is proposed and implemented by [16]. This system consists of three modules out of which two modules work as a controller. The microphone is a handheld module, central and appliances are controller modules. Handheld microphone module is based on PC which uses a ZigBee protocol and central controller module. The working mechanism of this system is that it uses Microsoft API for voice recognition and a wireless network is established using RF ZigBee module. GSM Based Home Automation System is proposed by [17] using Global System for Mobile communication (GSM) consists of a GSM modem, smartphone and a microcontroller PIC16F887. This microcontroller is connected with home appliances through relays and a serial communication between GSM modem and a microcontroller PIC16F887 is done with RS232. Moreover, a GSM modem is interfaced with a microcontroller which is used to encode and decode the SMS received for the purpose of execution of the specific commands.

The Internet of Things (IoT) based home automation system is presented by [18] which is used for controlling and

monitoring of home appliances based on Internet of Things (IoT) technology. This system consists of controlling devices, smartphone, software application and a micro web server. The system uses three main modules include remote environment, gateway environment and home environment which has the capability to control energy consumption of security, power plugs, door and gate, lightings, air conditioners, refrigerators etc. Another system is proposed by [19] based on the Ethernet system which is used for monitoring real-time tracking and switching information of the devices. The hardware architecture of this system consists of Intel Galileo 2<sup>nd</sup> generation board, smartphone and Android-based software application to monitor and control the security of homes in case of threats, fire or suspicious activities.

The monitoring and controlling of the home environment using wireless sensors, web server (Apache) and Raspberry Pi is proposed by [20]. The interface of this system is GUI which is easy and convenient for the users to interact with it anytime and anywhere. The hardware architecture of this system contains Arduino microcontroller Atmega 2560 using an Arduino Wi-Fi shield. A relay switch is also being used to send control signals from the Atmega 2560 to the home appliances. The web interface consists of buttons that permit the users to turn ON/OFF a device. The Html, .txt and PHP files are used to store data. The introduction of home automation for controlling and monitoring of home appliances, cooling, security, heating etc. measures over the internet is getting more popular nowadays. One of the beneficial effects it has on the environment is to optimize energy consumption and reduction in energy consumption rates. With the advent of smart metering technology, the consumers are able to monitor and control energy consumption at home which will lead towards cost-effective approach and thus helps the residents to make energy and cost adjustments accordingly [21]. The concept of smart metering integrated with the IoT has given rise to convert buildings and homes into efficient energy-aware environments. The researchers are interested to integrate the IoT in smart grid for the home automation solutions for the intent of saving energy, efficient controlling and to ensure continuous energy supply to the community. The IoT has this potential to provide intelligent, efficient and cost-effective solutions to society for the sake of their convenient, comfortable, better and safe personal lifestyle. The rapid practice of the home automation and with the advent of energy monitors, smart inverters, 21<sup>st</sup>-century new generation batteries for storage, solar, wind, geothermal energy has joined the IoT for optimizing energy consumption and efficiency. The renewable energy resources such as solar, wind, geothermal etc. are available which plays a significant role in the development of smart home environment [22]. The geothermal energy is currently being used for many smart homes in the world. It utilizes a grounded heat pump for saving energy demand and its consumption over time. Furthermore, smart environmental sensors are extensively being used at home as a key element of the Internet of Things (IoT) which provides monitoring and feedback for all indoor environmental activities. These sensors can measure humidity, temperature, home artificial lighting effects and sunlight.

### III. METHODOLOGY

This research is engineering and exploratory study with the aim of observing existing solutions and proposed a new approach for home automation for environmental sustainability. In order to identify the research problem, we have used 5W1H (sometimes referred to as Five Ws and How) questions approach whose answers are considered basic in information gathering or problem-solving. In Fig. 1, we can see the problem addressed in this paper by asking 5Ws (who, what, where, when, why) and 1H (how) about a problem taken up for improvement. It has also been observed that non-

automated homes have a significant impact on stakeholders, economy and global environment. In order to validate the impact on society, we have used a descriptive approach in nature by designing a survey questionnaire as an instrument to collect required data. The survey is used to validate the impact of home automation on stakeholders, economy and environment in a sustainable development perspective. With the rapid development of IoT, we are primarily focused on improving energy consumption, green technology and environmental sustainability through integrated home automation strategy for the betterment of the society and the global world.

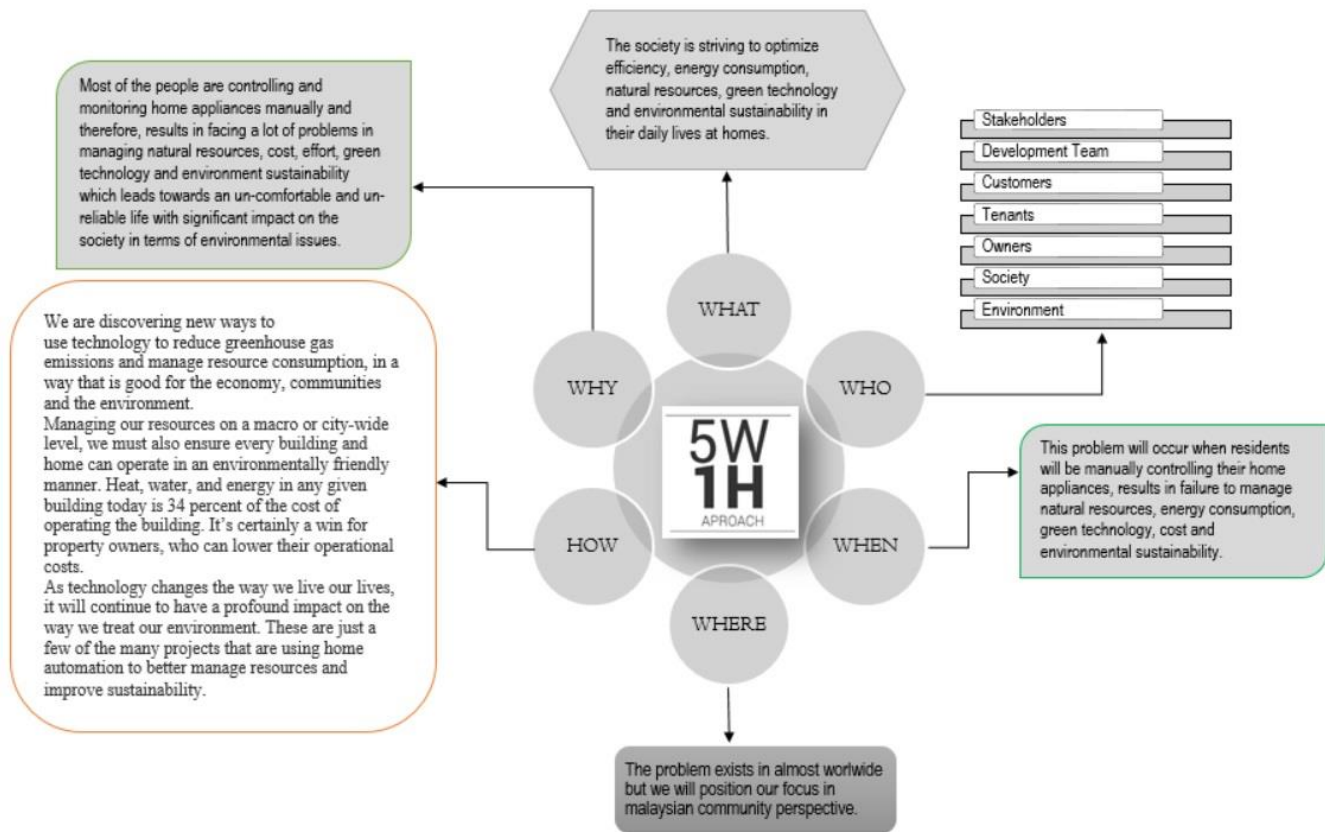


Fig. 1. 5W1H Problem Identification Approach.

### IV. PROPOSED ARCHITECTURE

The proposed architecture highlights an integrated home automation conceptual approach that optimizes energy consumption considering the environmental sustainable strategies using IoT. The proposed integrated home automation conceptual architecture is shown in Fig. 2 with the aim to optimize effort, cost, security, indoor activities and energy consumption by using renewable resources (solar, wind and geothermal) for the residential sector. Moreover, it is designed and developed by using currently available wireless communication services, equipment and devices through the home network. The residents can control, monitor, and manage energy usage and all home appliances of their choices over the Internet through smartphones using 3G/4G or other network availability options.

The home gateway acts as a data link layer connected with the Internet and home appliances which can be controlled and monitored through the remote client user interface either mobile devices, laptops or other communication devices. The user interface acts as a presentation layer through which the user may interact with. Besides, due to IoT technology, this system will be manageable and accessible from anywhere in the world. The monitoring system is incorporated in this architecture for monitoring the appliances in order to know the energy consumed by such devices. This architecture is a centre of renewable energy systems which are incorporated with home automation technique and smart meters communication for controlling and monitoring home appliances by achieving the aim of optimizing energy consumption and environmental sustainability. The smart meter is used for regular monitoring of energy consumption over time which can be achieved through taking a reading on an hourly or daily basis.

Accordingly, this system provides a significant capability of accessing separate energy system of their own choice by changing the energy system's status for best energy utilization. Several areas are controllable using this approach includes a new generation charging station for the chargeable electrical devices. The geothermal and wind energy produces Alternative Current (AC), a high voltage which needs to be converted into low-voltage for domestic purposes. For economic reasons, the increase and decrease in voltage for transmission and home utilization respectively can only be accomplished by using a step-up and step-down transformer. For this conversion of high-voltage to low-voltage, a step-

down transformer is used in domestic consumption. Similarly, in the case of solar energy, it produces direct current (DC) and it needs to be converted in AC which is achieved through using a converter for domestic energy utilization.

In addition, the Government green awareness program is combined to bring awareness among people that could help them by assisting through green awareness campaigns and participatory involvements. This could also be achieved successfully by using social media, advertisements, newspapers, magazines, blogs, interactive simulations, Web portals, etc.

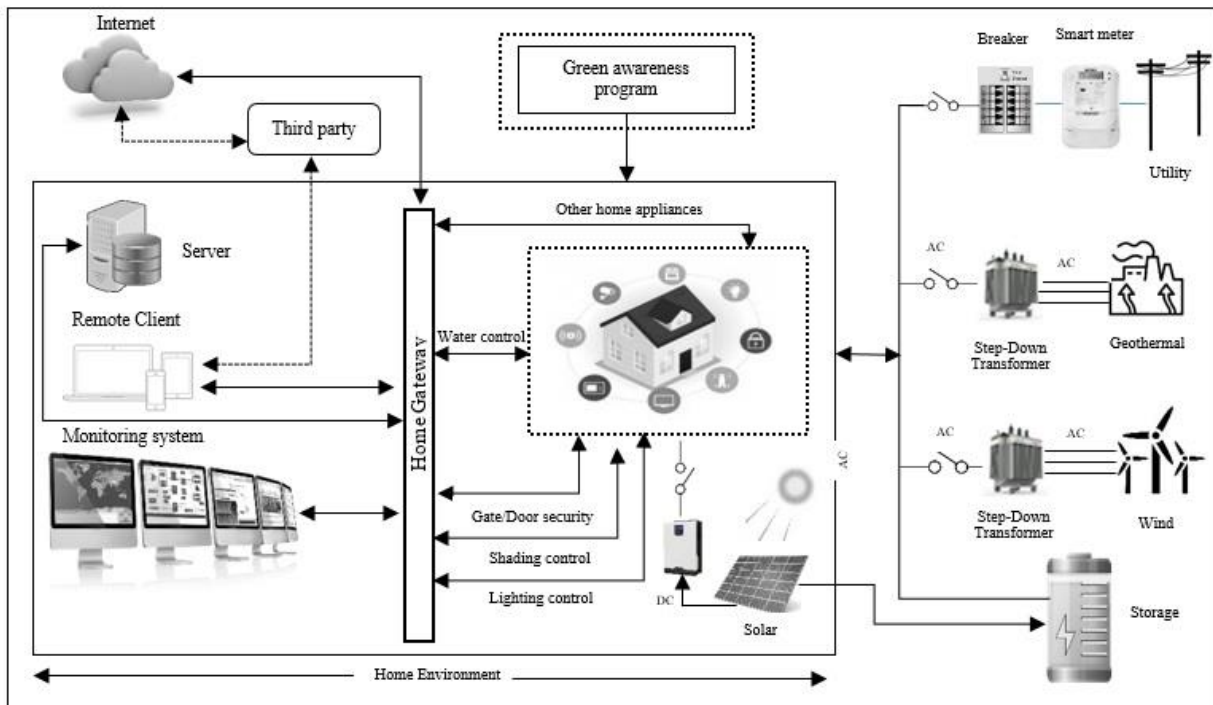


Fig. 2. Integrated Home Automation Conceptual Architecture.

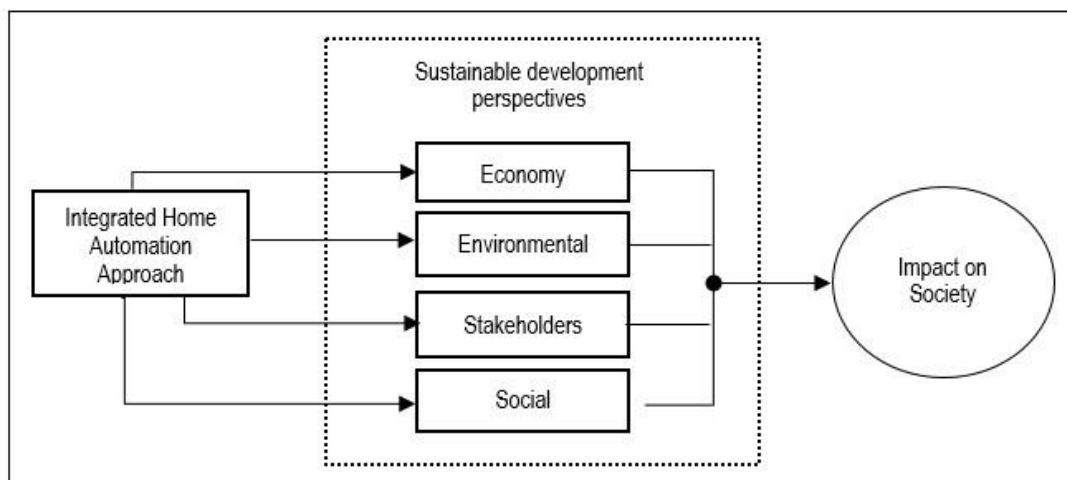


Fig. 3. Structure of Impact Model.

## V. IMPACT OF PROPOSED APPROACH ON SOCIETY

### A. Structural Impact Model

Fig. 3 illustrates the key structure model. Our research question is: What are the least impacts of home automation on society in a sustainable development perspective? We were interested in knowing the relationship between home automation approach and its impact on the society in view of economy, environment, stakeholders and social. We hoped to show clearly the impact (or lack thereof) of these relationships.

### B. Data Collection Methodology

A comprehensive survey was conducted among a target audience that included 20 questions regarding sustainable development perspective through an online questionnaire using Google forms. The measures were tested using a 5-point Likert-type scale ranging from “strongly disagree” to “strongly agree”. The purpose of this survey was to validate the least impact of the home automation system on society in a sustainable development perspective. We have divided the population into two main groups. In the first group, we ensured that the participants are computer literate and in the second group we prioritized those who have enough knowledge of environmental engineering and or sciences.

Our work consisted of three phases: 1) creation of the questionnaire, 2) collection of data, and 3) data analysis. In the first phase, a relationship is established between home automation, a green awareness program and environmental sustainability which are the key elements of our proposed solution. The relationship among these attributes indicates the impact of the architecture on the sustainable development and therefore to society.

We then created close-ended questions inquiring on how they can be helpful for establishing a relationship successfully. In the second step, we have used two modes of distributions of the questionnaire 1) manual and 2) online. In the first mode, the questionnaire was distributed manually among the students of these two groups at the Universiti Teknologi Malaysia and outside the community. In the second mode, we sent an online questionnaire link [23] using WhatsApp and E-mails by ensuring that it should be delivered to the respective target audience. In the second phase, the data was collected through Google forms in .csv file format. In the third phase, the .csv file was imported and statistically analyzed using IBM SPSS statistics for the compilation of results. The sample from 112 respondents was checked for missing indicators. It is found that only 3 (2.6%) cases had missing data for one or two of their indicators which appeared randomly. Thus, we decided to keep those cases with mean value substitution. The IBM SPSS statistics version 23 was used to analyze sample responses, standard deviation, skewness and kurtosis for data normality and Cronbach's alpha ( $\alpha$ ) test for reliability.

## VI. RESULTS AND DISCUSSION

The total of 112 out of 165 questionnaires was received resulting in 67.87% response rate. The sample was primarily males (71, 63.4%) and females (41, 36.6%) with a mean age of 37.33 (range, 18 to 60 years). A majority of respondents

had undergraduate (61, 54.5%) and postgraduate (38, 33.9%) qualification as shown in Table I.

The questionnaire was divided into four categorized by ID's such as ECO (economy), ENV (environmental), SOC (social) and STH (stakeholders) in order to establish a relationship between home automation approach and its impact on the society in sustainable development perspective as shown in Table II. It was observed that for economy (ECO2.1, 2.2 and 2.4), environment (ENV3.1 – 3.4), stakeholders (STH1.1 – 1.8) and social (SOC4.1 and 4.5) perspective, the mean score ranged from 1.94 to 2.75 out of total score of 5 indicating that the respondents were “agreed” on average for impact of the home automation on the society. It was found that for SOC4.2 – 4.4 (highlighted in grey), the mean range showed that the respondents neither agreed nor disagree. Thus, for SOC4.2 we had taken it towards “disagree” that the community should have knowledge regarding the role of home automation for a cleaner environment. It was also observed that for SOC4.3 and SOC4.4 the Row N% is 37.5% and 32.1% respectively which was greater than all other indicators with respect to SOC4.3 and 4.4 hence, showed its significance.

The overall results supported the impact model and revealed that home automation plays a significant role and contribute to sustainable development. The majority of the respondents were agreed that the advancements in home automation technology are an effort to boost the economy. It also provides a greener environment, reduces the usage of energy, effort, natural resources, and saves costs of living and time consumption and therefore contributing to society. Table III reports the data normality of the items used to measure our impact model.

The Standard Deviation (SD) was used to measure the dispersion of the data from the mean values and technically it is volatility. The SD should be used to accurately summarize the descriptive data [24]. The results indicated that the standard deviation for all values was low and it was close to the mean values significantly ranged from ECO2.1 – STH1.8. It has been investigated that the positive and negative skewness and kurtosis values for a perfect normal distribution is between 1.0 and -1.0 and -3 and 3 respectively if the sample size is greater than 100 and less than 200 as a suggested benchmark [25]. In our case, the sample size is 112 thus, the skewness and kurtosis values were between the optimal normal distribution ranges indicated that the results were “disagree” that the community should have knowledge regarding the role of home automation for a cleaner environment. It was also observed that for SOC4.3 and SOC4.4 the Row N% is 37.5% and 32.1% respectively which was greater than all other indicators with respect to SOC4.3 and 4.4 hence, showed its significance. The overall results supported the impact model and revealed that home automation plays a significant role and contribute to sustainable development. The majority of the respondents were agreed that the advancements in home automation technology are an effort to boost the economy. It also provides a greener environment, reduces the usage of energy, effort, natural resources, and saves costs of living and time consumption and therefore contributing to society.

TABLE. I. SAMPLE DEMOGRAPHIC CHARACTERISTICS

		N	N %
Gender	Male	71	63.4%
	Female	41	36.6%
Age	18-40	99	88.4%
	41-60	13	11.6%
	above 60	0	0.0%
Qualification	High School	2	1.8%
	College	6	5.4%
	Undergraduate	61	54.5%
	Post Graduate	38	33.9%
	Doctoral	5	4.5%

TABLE. II. RESPONDENTS' DISTRIBUTION

ID	Strongly agree 1		Agree 2		Neither agree nor disagree 3		Disagree4		Strongly Disagree5		Mean Statistic
	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	
ECO2.1	18	16.1%	74	66.1%	14	12.5%	6	5.4%	0	0.0%	2.0714
ECO2.2	8	7.1%	56	50.0%	27	24.1%	16	14.3%	5	4.5%	2.5893
ECO2.4	13	11.6%	57	50.9%	29	25.9%	12	10.7%	1	0.9%	2.3839
ENV3.1	11	9.8%	41	36.6%	27	24.1%	30	26.8%	3	2.7%	2.7589
ENV3.2	13	11.6%	63	56.3%	21	18.8%	13	11.6%	2	1.8%	2.3571
ENV3.3	26	23.2%	67	59.8%	16	14.3%	1	0.9%	2	1.8%	1.9821
ENV3.4	16	14.3%	73	65.2%	20	17.9%	2	1.8%	1	0.9%	2.0982
SOC4.1	15	13.4%	62	55.4%	26	23.2%	9	8.0%	0	0.0%	2.2589
SOC4.2	7	6.3%	29	25.9%	30	26.8%	40	35.7%	6	5.4%	3.0804
SOC4.3	7	6.3%	27	24.1%	33	29.5%	42	37.5%	3	2.7%	3.0625
SOC4.4	7	6.3%	31	27.7%	32	28.6%	36	32.1%	6	5.4%	3.0268
SOC4.5	9	8.0%	40	35.7%	35	31.3%	26	23.2%	2	1.8%	2.7500
STH1.1	28	25.0%	64	57.1%	18	16.1%	2	1.8%	0	0.0%	1.9464
STH1.2	10	8.9%	64	57.1%	26	23.2%	12	10.7%	0	0.0%	2.3571
STH1.3	21	18.8%	64	57.1%	20	17.9%	6	5.4%	1	0.9%	2.1250
STH1.4	19	17.0%	68	60.7%	19	17.0%	6	5.4%	0	0.0%	2.1071
STH1.5	6	5.4%	51	45.5%	29	25.9%	24	21.4%	2	1.8%	2.6875
STH1.6	26	23.2%	61	54.5%	19	17.0%	5	4.5%	1	0.9%	2.0536
STH1.7	24	21.4%	75	67.0%	9	8.0%	3	2.7%	1	0.9%	1.9464
STH1.8	16	14.3%	50	44.6%	32	28.6%	12	10.7%	2	1.8%	2.4107

Table III reports the data normality of the items used to measure our impact model. The Standard Deviation (SD) was used to measure the dispersion of the data from the mean values and technically it is volatility. The SD should be used to accurately summarize the descriptive data [24]. The results indicated that the standard deviation for all values was low and it was close to the mean values significantly ranged from ECO2.1 – STH1.8. It has been investigated that the positive and negative skewness and kurtosis values for a perfect normal distribution is between 1.0 and -1.0 and -3 and 3

respectively if the sample size is greater than 100 and less than 200 as a suggested benchmark [25]. In our case, the sample size is 112 thus, the skewness and kurtosis values were between the optimal normal distribution ranges indicated that the results were significant.

In order to understand and validate the model, whether the constructs in the questionnaire are reliable measures, we examined the reliability and validity of each construct of our survey. For this purpose, a Cronbach's alpha analysis was conducted for the reliability on a total of 20 constructs.

According to Van Zyle et al. [26],  $\alpha$  value close to 0 indicates that the results are not reliable and close to 1 suggested that the results are very reliable. As a rule of thumb,  $\alpha \geq 0.70$  is considered reliable. It was found that the Cronbach's alpha ( $\alpha$ ) level was 0.796 and Cronbach's alpha ( $\alpha$ ) based on standardized items was 0.803 as shown in Table IV which indicates that our constructs have a high level of inter-item or internal reliability.

Table V presents the Cronbach's alpha items total statistics which provides with an overall reliability coefficient for a set of variables if any particular item was deleted from the construct. The column "Cronbach's alpha if item deleted" ranged from .779 to .794 (highlighted in grey) indicated "Good" [27] Cronbach's alpha internal consistency for the set of constructs.

The results of the table indicated that the removal of any question would result in a lower Cronbach's alpha means that the set of items are closely related as a group. The removal of any item from the constructs will affect the Cronbach's alpha value leads to the unreliability of the questionnaire constructs.

The bivariate Pearson Correlation was conducted for the validity of variables and to measure the strength and direction of the relationship between variables. It yields a correlation

coefficient,  $r$ , which measures any linear trend between two or more variables. The benchmark value of ' $r$ ' always lies between -1 and 1 [28].  $r = 0$ , indicates no linear relationship,  $r \geq 1$ , means a perfect positive linear relationship and  $0 < r < 1$  indicates positive linear trend between the variables [29]. Table VI shows a Pearson product-moment correlation for examining the validity and relationship between variables. It was observed that the values at the diagonals are statistically significant at the 0.01 and 0.05 benchmark level hence, indicated its validity.

The linear trend between variables is positively correlated except SOC4.3 (social) and STH1.7 (stakeholder) which is -.11. The relationship between SOC4.1 and 4.2 is .27 means that SOC4.1 (social) was more strongly positively related to SOC4.2 (social). It was found that SOC4.2 explains much more of the variability in SOC4.1. Similarly, the relationship between SOC4.2 and ENV3.3 is .30 indicated significant value means that SOC4.2 (social) was more strongly positively related to ENV3.3 (environment). It was found that ENV3.3 explains much more of the variability in SOC4.2. The share of variability was also calculated. It was found that the coefficient correlation ( $r$ ) between STH1.3 (stakeholder) and ECO2.1 (economy) is .39 which yields 15.21%. Hence, STH1.3 shares about 15.21% of its variability with ECO2.1.

TABLE. III. MEAN, STD. DEVIATION, SKEWNESS AND KURTOSIS OF KEY MEASURES

ID	N	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ECO2.1	112	2.0714	.70665	.834	.228	1.384	.453
ECO2.2	112	2.5893	.97309	.729	.228	.001	.453
ECO2.4	112	2.3839	.86207	.539	.228	.047	.453
ENV3.1	112	2.7589	1.04188	.111	.228	-.938	.453
ENV3.2	112	2.3571	.89902	.818	.228	.425	.453
ENV3.3	112	1.9821	.75911	1.162	.228	3.027	.453
ENV3.4	112	2.0982	.68392	.906	.228	2.723	.453
SOC4.1	112	2.2589	.79123	.501	.228	.035	.453
SOC4.2	112	3.0804	1.04095	-.212	.228	-.809	.453
SOC4.3	112	3.0625	.98896	-.355	.228	-.739	.453
SOC4.4	112	3.0268	1.03506	-.104	.228	-.798	.453
SOC4.5	112	2.7500	.96329	.092	.228	-.742	.453
STH1.1	112	1.9464	.69541	.399	.228	.179	.453
STH1.2	112	2.3571	.79250	.593	.228	-.025	.453
STH1.3	112	2.1250	.80678	.816	.228	1.134	.453
STH1.4	112	2.1071	.73958	.643	.228	.657	.453
STH1.5	112	2.6875	.93028	.393	.228	-.686	.453
STH1.6	112	2.0536	.81472	.817	.228	1.113	.453
STH1.7	112	1.9464	.69541	1.218	.228	3.056	.453
STH1.8	112	2.4107	.92565	.475	.228	-.037	.453
Valid N (listwise)	112						



TABLE. IV. CRONBACH'S A RELIABILITY STATISTICS

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.796	.803	20

TABLE. V. CRONBACH'S A ITEMS TOTAL STATISTICS

Item-Total Statistics					
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
SOC4.1	45.7946	56.435	.364	.301	.787
SOC4.2	44.9732	54.369	.386	.400	.786
ECO2.4	45.6696	55.845	.372	.247	.786
ENV3.3	46.0714	56.571	.371	.399	.787
STH1.1	46.1071	57.826	.291	.409	.791
STH1.8	45.6429	54.304	.456	.390	.781
STH1.6	46.0000	55.514	.429	.472	.783
STH1.7	46.1071	56.871	.384	.428	.786
SOC4.3	44.9911	56.459	.266	.505	.794
SOC4.4	45.0268	55.270	.328	.580	.790
STH1.5	45.3661	55.604	.354	.385	.787
ENV3.1	45.2946	54.786	.357	.493	.788
SOC4.5	45.3036	56.015	.308	.392	.791
ECO2.1	45.9821	57.225	.342	.376	.788
STH1.3	45.9286	54.698	.506	.426	.779
STH1.4	45.9464	55.637	.471	.467	.781
ECO2.2	45.4643	56.521	.268	.314	.793
STH1.2	45.6964	56.664	.343	.326	.788
ENV3.2	45.6964	55.673	.365	.562	.787
ENV3.4	45.9554	57.629	.317	.392	.789

TABLE. VI. CORRELATION MATRIX OF THE CONSTRUCTS

	SOC4.1	SOC4.2	ECO2.4	ENV3.3	STH1.1	STH1.8	STH1.6	STH1.7	SOC4.3	SOC4.4
SOC4.1										
SOC4.2	.27**									
ECO2.4	.10	.23*								
ENV3.3	.08	.30**	.21*							
STH1.1	.29**	-.00	.15	.19*						
STH1.8	.23*	.10	.14	.23*	.23*					
STH1.6	.21*	.05	.26**	.28**	.34**	.54**				
STH1.7	.14	.09	.23*	.36**	.27**	.36**	.45**			
SOC4.3	.08	.25**	.12	-.13	-.02	.04	-.07	-.11		
SOC4.4	.20*	.27**	.19*	-.06	-.07	.09	-.00	.05	.61**	
	STH1.5	ENV3.1	SOC4.5	ECO2.1	STH1.3	STH1.4	ECO2.2	STH1.2	ENV3.2	ENV3.4
STH1.5										
ENV3.1	.40**									
SOC4.5	.26**	.36**								
ECO2.1	-.05	-.04	.12							
STH1.3	.10	.22*	.03	.39**						
STH1.4	.04	.06	.10	.35**	.32**					
ECO2.2	.15	-.06	.01	.09	.24*	.21*				
STH1.2	.04	.09	-.06	.19*	.22*	.35**	.25**			
ENV3.2	.11	-.1	.15	.16	.31**	.39**	.42**	.30**		
ENV3.4	-.02	.05	-.02	.26**	.27**	.26**	.16	.23*	.50**	

\*\* Correlation is significant at the 0.01 level (2-tailed)

\* Correlation is significant at the 0.05 level (2-tailed)

N=112

## VII. CONCLUSION AND FUTURE DIRECTION

The concept of the Internet of Things (IoT) is one of the fundamental technologies to attain the objective of affordable energy at home and environment sustainability. A home automation approach plays a significant role in managing efficiency and to improve the consumption of renewable energy resources. In this paper, an integrated cost-effective, comfortable and reliable approach is proposed with IoT based home automation technique. Besides, smart meter, solar, wind and geothermal renewable energy resources, and green awareness program are incorporated with home automation to minimize the demand of energy and to achieve the goal of green technology and environmental sustainability for the society. This approach also plays a significant role to optimize convenience, comfortability, cost, environment, behaviour and promote awareness among society. The brief reviews on the recent advancements of different type of wireless communication techniques like Bluetooth, Voice Recognition, ZigBee, GSM and Wi-Fi are investigated which may be used during real implementation of the proposed approach. The important element of green awareness program is combined with this approach which could offer assistance to society through a communication medium such as Web portals, wikis, blogs, and interactive simulations. However, the IT industry and society should change their attitude towards positivity for the sake of addressing environmental issues and must take suitable measures to promote and adopt climate-friendly behaviour, strategies and procedures. Moreover, a relationship is established between 4IR enabling technologies-IoT, smart home and renewable energy resources and its impact on the society in a sustainable development perspective. However, a survey is conducted to identify the least impact of the proposed solution on the environment and therefore to the society for its validity.

The survey is statistically analyzed using IBM SPSS statistics in which mean, standard deviation, skewness and kurtosis are used for normal distribution. Furthermore, Cronbach's alpha and Pearson correlation are statistically analyzed for reliability and validity. The results significantly revealed that the usage of home automation has a great impact on society in a sustainable development perspective.

A lot of research still needs to be investigated in this domain. In future work, we recommend that the researchers may explore fog computing and big data for optimizing renewable energy consumption and a large amount of data produced within the IoT.

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YASIR MAHMOOD  
<https://orcid.org/0000-0003-1578-5229>

## REFERENCES

- [1] Z. Zenn Bien. Human-friendly Man-Machine Interaction in Smart Home. Keynote speech at the 3rd International Conference On Smart homes and health Telematic, Sherbrooke, Québec, Canada, July 4-6, 2005.
- [2] G. Broll, E. Rukzio, M. Paolucci, M. Wagner, A. Schmidt, H. Hussmann, PERCI: pervasive service interaction with the internet of things, *IEEE Internet Computing* 13 (6) (2009) 7481.
- [3] Abdeen Mustafa Omer, Energy, environment and sustainable development, *Renewable and Sustainable Energy Reviews*, Volume 12, Issue 9, 2008, Pages 2265-2300, ISSN 1364-0321,
- [4] P. Sathyamoorthy, E. C.-H. Ngai, X. Hu, and V. C. M. Leung, "Energy efficiency as an orchestration service for mobile Internet of Things," in *Proc. 7th IEEE Int. Conf. Cloud Comput. Technol. Sci.*, Nov./Dec. 2015, pp. 1-8.
- [5] L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A survey," *Comput. Netw.*, vol. 54, no. 15, pp. 2787-2805, Oct. 2010.
- [6] C. Perera, C. H. Liu, S. Jayawardena, and M. Chen, "A survey on Internet of Things from industrial market perspective," *IEEE Access*, vol. 2, pp. 1660-1679, Jan. 2014.
- [7] L. Da Xu, W. He, and S. Li, "Internet of Things in industries: A survey," *IEEE Trans. Ind. Informat.*, vol. 10, no. 4, pp. 2233-2243, Nov. 2014.
- [8] Mankoff, J., Matthews, D., Fussell, S.R. and Johnson, M. Leveraging Social Networks to Motivate Individuals to Reduce their Ecological Footprints HICSS 2007, Hawaii, 2007.
- [9] Beckmann, C., Consolvo, S. and LaMarca, A. Some Assembly Required: Supporting End-User Sensor Installation In Domestic Ubiquitous Computing Environments Ubicomp 2004, Springer-Verlag, 2004.
- [10] Arroyo, E., Bonanni, L. and Selker, T. Waterbot: exploring feedback and persuasive techniques at the sink CHI 2005, ACM, Portland, Oregon, USA, 2005.
- [11] O. Orhan, D. Gunduz, and E. Erkip, "Energy harvesting broadband communication systems with processing energy cost," *Wireless Communications, IEEE Transactions on*, vol. 13, no. 11, pp. 6095-6107, Nov 2014.
- [12] K. Davaslioglu and E. Ayanoglu, "Quantifying potential energy efficiency gain in green cellular wireless networks," *Communications Surveys Tutorials, IEEE*, vol. 16, no. 4, pp. 2065-2091, Fourth-quarter 2014.
- [13] B. Wang, Y. Wu, F. Han, Y.-H. Yang, and K. Liu, "Green wireless communications: A time-reversal paradigm," *Selected Areas in Communications, IEEE Journal on*, vol. 29, no. 8, pp. 1698-1710, September 2011.
- [14] R. Piyare and M. Tazil, "Bluetooth based home automation system using cell phone," *Consumer Electronics (ISCE), 2011 IEEE 15th International Symposium on*, Singapore, 2011, pp. 192-195.
- [15] S. Sen, S. Chakrabarty, R. Toshniwal, A. Bhaumik, "Design of an intelligent voice-controlled home automation system", *International Journal of Computer Applications*, vol. 121, no.15, pp. 39-42, 2015.
- [16] H. AlShu'eili, G. S. Gupta and S. Mukhopadhyay, "Voice recognition based wireless home automation system," *Mechatronics (ICOM), 20114th International Conference On*, Kuala Lumpur, 2011, pp. 1-6.
- [17] R. Teymourzadeh, Salah Addin Ahmed, Kok Wai Chan and Mok Vee Hoong, "Smart GSM based Home Automation System," *Systems, Process & Control (ICSPC), 2013 IEEE Conference on*, Kuala Lumpur, 2013, pp. 306-309.
- [18] R. Piyare, "Internet of things: ubiquitous home control and monitoring system using android based smartphone", *International Journal of Internet of Things*, vol. 2, no. 1, pp. 5-11, 2013.
- [19] Gupta, P., & Chhabra, J. (2016). IoT based Smart Home design using power and security management. 2016 International Conference on Innovation and Challenges in Cyber Security (ICICCS-INBUSH). doi:10.1109/iciccs.2016.7542317.
- [20] D'souza, M., Wilfred, N., Pereira, R., Rayen, T., & Telgote, A. (2017). Home automation using Internet of Things. 2017 International

- Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS). doi:10.1109/icecds.2017.8389498.
- [21] L. Song, Y. Xiao, and M. van der Schaar, "Demand-side management in smart grids using a repeated game framework," *Selected Areas in Communications, IEEE Journal on*, vol. 32, no. 7, pp. 1412–1424, July 2014.
- [22] M.W. Ahmad, M. Mourshed, D. Mundow, M. Sisinni, Y. Rezgui, Building energy metering and environmental monitoring – a state-of-the-art review and directions for future research, *Energy Build.* 120 (2016) 85–102.
- [23] <https://tinyurl.com/y67bfg9>.
- [24] Barde MP, Barde PJ. What to use to express the variability of data: Standard deviation or standard error of mean?.*Perspect Clin Res.* 2012;3(3):113-6.
- [25] 2005 American Statistical Association *Journal of Business & Economic Statistics* January 2005, Vol. 23, No. 1 DOI 10.1198/073500104000000271.
- [26] S.M. van Zyle, N. Heinz, D.G. Nel, On the distribution of the maximum likelihood estimator of Cronbach's alpha, *Psychometrika* 65 (2000) 271–280.
- [27] DeVellis, R.F. (2012). *Scale development: Theory and applications*. Los Angeles: Sage. pp. 109–110.
- [28] Puth, M.-T., et al. (2014). "Effective use of Pearson's product–moment correlation coefficient." *Animal Behaviour* 93: 183-189.
- [29] Schober, P., et al. (2018). "Correlation Coefficients: Appropriate Use and Interpretation." *Anesth Analg* 126(5): 1763-1768.

APPENDIX

The following twenty sustainable development attributes were measured based on a five-point Likert scale. The scale was weighed as strongly agree, agree, neither agree nor disagree, disagree and strongly disagree.

No.	Constructs
SOC4.1	I have sufficient knowledge about the current environmental issues.
SOC4.2	I believe that the community has enough knowledge regarding the role of home automation for a cleaner environment.
ECO2.4	Rapid advancements in home automation technology is an effort to boost the economy can contribute to environmental degradation.
ENV3.3	Personal awareness of home automation is an important factor in the protection of the environment.
STH1.1	Home Automation System (HAS) through Internet of Things (IoT) contribute to a better quality of life
STH1.8	Do you think it gives more freedom of mobility to society?
STH1.6	According to your opinion, it gives people more control over and productive in their daily lives.
STH1.7	Home automation with renewable energy is beneficial for energy providers in order to maintain electricity and gas grid stations.
SOC4.3	Home automation through IoT is not helpful because they do not explain things in terms I understand.
SOC4.4	The home automation system is not designed for use by ordinary people.
STH1.5	People are too dependent on home automation through IoT technology to do things for them.
ENV3.1	Too much home automation through IoT technology distracts people to a point that is harmful.
SOC4.5	I do not feel confident to implement automation with a place that can only be reached physically.
ECO2.1	It reduces the usage of energy, effort, wastage of natural resources, saves costs of living and convenience, and time consumption.
STH1.3	Do you think it helps to achieve the goal of a sustainable environment?
STH1.4	According to your understanding, it is the way for a cleaner and greener environment for future generations.
ECO2.2	Do you believe it provides low maintenance cost on home appliances, hence spent income on other services?
STH1.2	It helps in engaging and focusing on social activities while reducing home tasks.
ENV3.2	Do you think it saves natural resources and minimizes global warming?
ENV3.4	It brings significant impact on less energy consumption and cleaner environment through solar, wind and geothermal renewable energy.