INVESTIGATION ON THE IMPACT OF SMART BUILDINGS IN THE MODERN SOCIETY

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A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor (Hons.) of Electrical and Electronic Engineering

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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Date : _____

Specially dedicated to
my beloved family who supported me throughout
my degree for the past 4 years

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INVESTIGATION ON THE IMPACTS OF SMART BUILDINGS IN THE MODERN SOCIETY

ABSTRACT

Smart buildings are also known as intelligent buildings. This idea had actually come out way back in the 1980s. Smart buildings can actually be categorized into few categories which are hospital, industry, residential and so on. A lot of research has been done to investigate all the benefits that a smart building can provide such as energy management, reduction in the environmental impacts, increase in the ability of elderly people with physical disorder to live independently, ability to remotely control home appliances, a more comfortable and secure living environment and so on. The development of smart buildings is getting more and more popular and it is no longer a strange term for the society. Over the years, some research and investigation on smart buildings have been carried out to improve the functionality and efficiency in terms of the technologies and equipment usage for smart buildings. However, there are still some doubts on the possible impacts smart buildings will bring towards the society. This had been one of the reasons for the low implementation of these smart buildings. In order to further promote smart buildings in the future, some basic investigations must be carried out for the purpose of clearing the doubts of the society. In this project, the attitude of society, limitations of wireless sensor network, possible threats faced by smart home, some complaints of using smart metering and technologies for smart residential buildings is investigate.

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σ	specific conductivity, S m^{-1}
E_{rms}	effective amount of field in tissue, V m^{-1}
ρ	density of radiation-exposed tissue, gr cm^{-3}

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CHAPTER 1

INTRODUCTION

1.1 Background

Smart buildings were originally known as commercial building technology and it has changed the name recently in the year of 2010 (Anon., n.d.). The idea of this smart building was originally based on the concept of Energy Management. This concept is also known as Building Management System (BMS).

Building Management System (BMS) is actually a type of distributed control system. The main purpose of this system is to provide control, monitoring the building performance and as well as to obtain the optimization of building services. These services include the lighting systems, ventilation systems, HVAC system as well as heating systems within the building (Swarnalatha, et al., 2011). Optimization of these services reduces the negative impacts towards mother earth. This is because fossil fuels are the major energy sources used to generate electricity (S.M., et al., 2011). The types of energy source are shown in Figure 1.

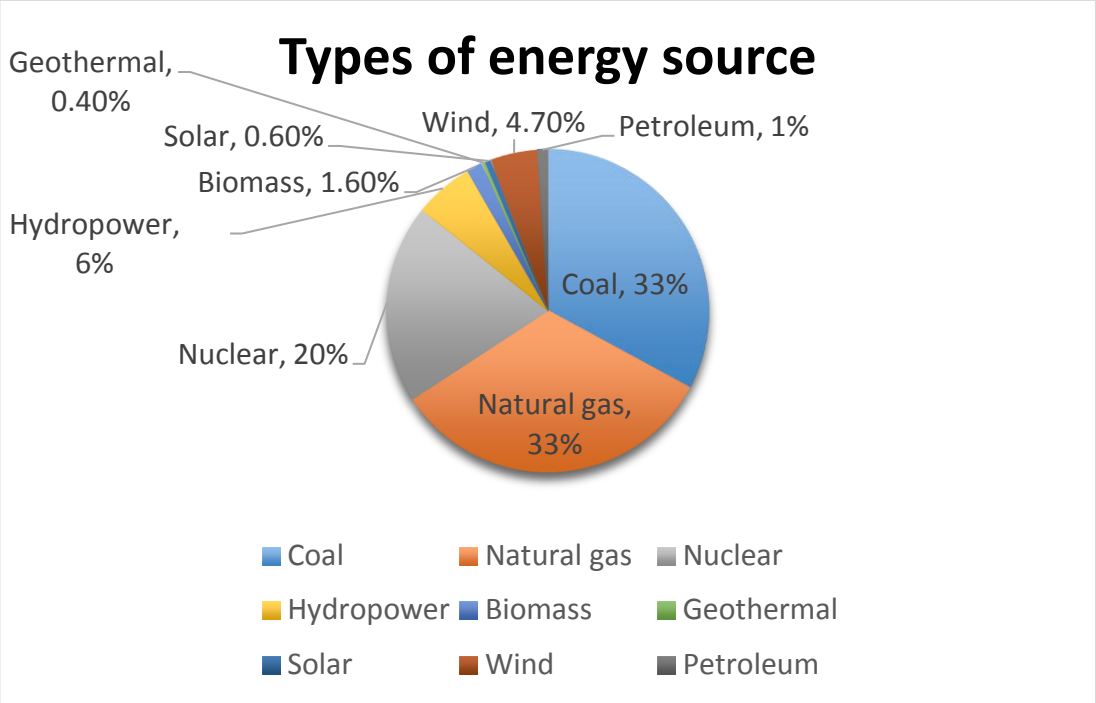

Figure 1.1: Energy Source use by United States (2015) (Anon., n.d.)

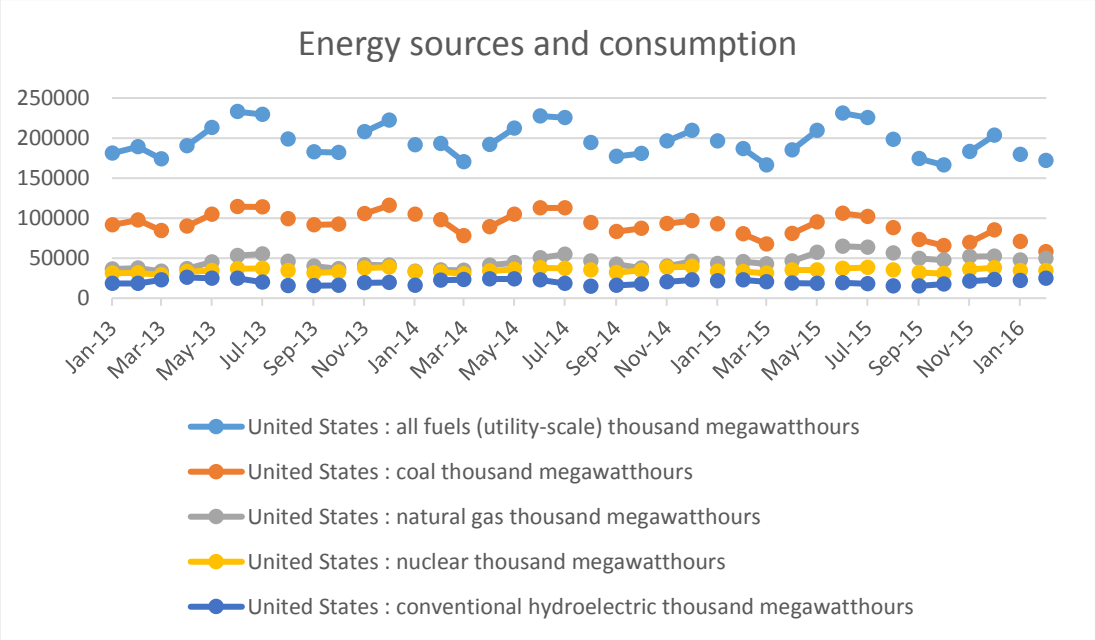

Figure 1.2: Energy Usage in United States (Anon., n.d.)

When the energy consumption of a building is being managed and controlled in a smart way, the demand load reduces. This in returns reduces the electricity

consumption and therefore reduces the usage of all the fossil fuels thereby reduction in release of carbon dioxide due to burning of fossil fuels. Windows Communication Foundation is a framework for building service orientation application. It allows the communications of the smart home systems and the technology used for the smart home. When these smart home systems and the technology are being link together, users are able to control them remotely (Yuli Purwati & Fandy Setyo Utomo, 2014)

1.2 Problem Statement

There has always been doubts among the people regarding the impacts the smart buildings will bring towards them. This is probably the main reason why smart buildings have not been implemented widely despite the benefits it brings towards the society. It is therefore important to carry out a detailed investigation on the impact of smart buildings so that more people will accept it. Hence, some investigations on the impacts of smart buildings have been proposed and discussed in this project. The main aim of this investigation is to clear the doubts of people about the possible impacts of smart buildings.

1.3 Rationale for the project

During this research, it is to investigate the impacts that smart building will bring towards modern society. Smart buildings are further categorize into hospital, residential, and commercial. This research will be focus on the impact of smart residential buildings toward modern society. From the literature review, it can see that the impacts that smart residential building consists of both advantages and disadvantages. In order for the society to have a deeper understanding towards smart residential buildings, it is required to carry out a more detail investigation on the selected impacts of smart residential buildings. In this project, it will focus on the impact which is the complaint of using smart technologies. Among the technologies

that are used such as smart security, monitoring system, HVAC, voice-command system, and so on. However, only the complaints based on the usage of smart meter is chosen to be studied. The specific absorption rate (SAR) for smart meters, automatic meter reading (AMR), and conventional meter have been identified

1.4 Aims and Objectives

There are a few aims that this study is being carry out

- To study the impacts of the usage of smart residential buildings in the modern society
- To aid the society to have a deeper understanding towards smart buildings

The objectives of this study are:

- To identify the possible impacts of smart residential buildings to the modern society
- To study the possible health issues of smart residential buildings towards modern society
- To do a comparison of Specific Absorption Rate (SAR) between smart meter, automatic meter reading (AMR) and conventional meter
- To conduct the simulation by using Matlab for calculation of Specific Absorption Rate (SAR)

1.5 Overview

There are 5 chapters in total for this final year project. All the chapters are listed below.

Chapter 1 – Introduction: This chapter discusses the background of smart buildings, the way that this smart buildings benefit the society and also a basic review of how this smart buildings work. This chapter include the problem statement

for this project. Besides that, it also include the aims to carry out this project and the objectives to be achieved.

Chapter 2 – Literature Review: This chapter includes the investigation of the impacts of smart residential buildings towards modern society. All the possible investigated impacts are listed in this chapter of the report.

Chapter 3 – Research Methodology: This chapter covers the further investigation of the selected impact listed in Chapter 2. It also include the method used to analyse the studied impact. The selected impact will be the drawbacks of smart meter and smart technology, however only the drawbacks of smart meter are further investigated. The method that's been used to further study this impact is through the Specific Absorption Rate (SAR).

Chapter 4 – Results and discussion: This chapter begin by obtaining the results through the method mention in Chapter 3 of this report. The obtained results will be used to compare between 3 different types of meters such as smart meters, automatic meter reading (AMR), and conventional meter. There will be further discussion based on the comparative between these meters and to conclude if smart meters will have a greater health impact towards modern society.

Chapter 5 – Conclusion and recommendations: This chapter presents the summary of the project. A recommendation is made by implementing energy generating tiles into smart residential buildings

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to understand the low implementation of the smart residential buildings despite of all the benefits that it brings towards the society, an investigation on the impacts of the smart residential buildings are carried out in this project. This is to allow further improvements to be done and to have a deeper understandings on the reason behind the low and slow implementations of smart residential buildings.

2.2 Energy efficiency

Every home has a few basic home appliances for daily purposes. Those home appliances include lighting, washing machine, air-conditioning, water heater etc. If these electronic devices do not manage well, for example consumers forget to switch it off after using it, it will amount to a high consumptions of electricity. With the number of home increases throughout the year as the population increases, it might lead to a high peak load demand. Figure 2.1 shows the variations of residential buildings from the year 2000 to the year 2016.

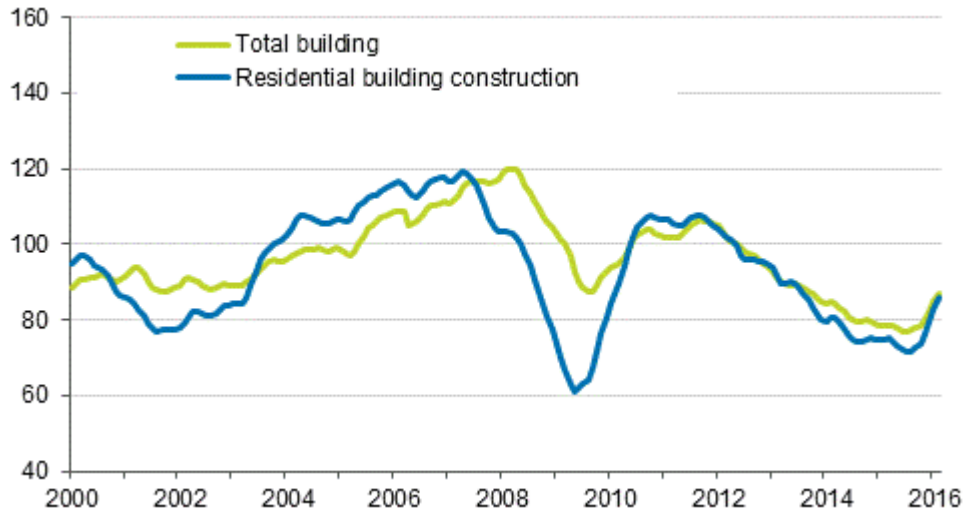

Figure 2.1: Building Statistics (Ylä-Jarkko, 2016)

Figure 2.2 shows the energy consumption for different sectors including residential, commercial, and industrial as well as transportation (Anon., n.d.). It can be observed that the energy consumption for all sector are quite high throughout the years. Hence it is very important to have good energy management for a building, else the energy consumption increases and causes lot of damages to the earth.

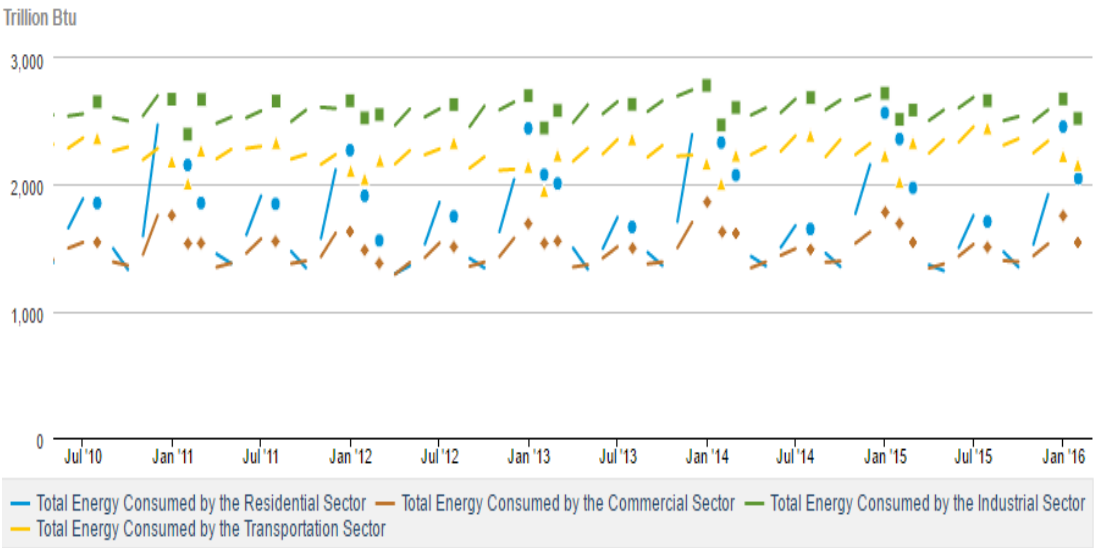

Figure 2.2: Energy Consumption for Different Sectors (Anon., n.d.)

The damage towards the earth can be reduced with the construction of smart residential buildings. (Attia & Ashour, n.d.). The energy can be managed by actually controlling the activities of the load (Zipperer, et al., 2013). For example, the air conditioning load can be managed by installing a temperature sensors to detect the changes in temperature and send instruction for the air-conditioning to switch off when the temperature drop below a certain value and vice versa (Attia & Ashour, n.d.). Besides temperature sensor, the smart residential buildings also consists of "intelligent" thermostat. The thermostat consists of a built in software which allow it to "observe" the activities of users, the time when the user switch on or off the air-conditioning, and then create a schedule in accordance to the observations (Cone, n.d.). Another method of controlling the usage of air-conditioning is through air-conditioning unit. This controlling method consists of the same operation concept as temperature sensor. The only difference is it allows user to key in the value of temperature for the air-conditioning or heater to achieve. In another word, when the surrounding temperature exceed the threshold value, the air-conditioning will operate When the temperature of the surrounding drops below the threshold values, the heater will operate (Bingol, et al., 2014).

Other than the above mention system, smart residential buildings also consists of lighting system. One of the method to control the lighting devices in home is by using a light-dependent resistor (LDR) (Bangali & Shaligram, 2013). The working principle of this resistor is on the amount of light incident on its surface. When the light intensity falling on its surface is high, the resistivity tends to drop but when it is low, the resistivity will increase. One of the application is LDR controlled transistor circuit. When the resistance increases, the voltage drop across the LDR sensor will increase as well. The transistor will be switch on when the voltage is high enough and hence the light will be turn on. An alternative sensor will be a motion sensor for controlling the lighting system. This motion sensor function by detecting the movement of the user and to provide instruction to the lighting system weather or not to switch on the light. Passive Infrared (PIR) sensor is one of the application of motion sensor (Shubha, et al., 2015). The PIR sensor releases passive infrared signals for the detection of heat source. In this case, users will be the heat source, whenever the sensor detect the users, it will send instruction for the light to turn on (Kumar K, et al., 2015).

The home appliances can also be remotely controlled with an Internet infrastructure built-in to the smart residential buildings. This infrastructure consists of client and server software and database section. The operation can be explained with the Figure 2.3

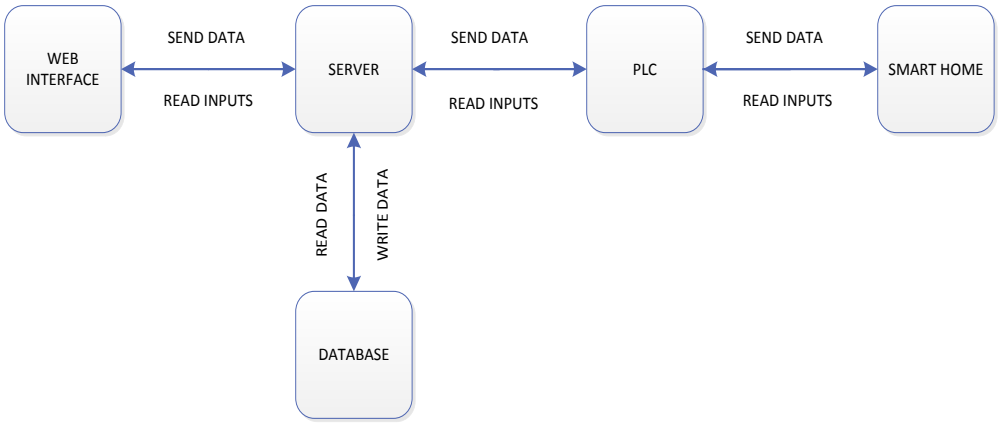

Figure 2.3: Software Interaction (Bingol, et al., 2014)

Consumers are able to interact with the smart home appliances with a computer, tablet or any smart devices through the Internet. The server works in bi-directional way. It records the instruction send by smart home to the database, and sends the saved control instruction to the smart residential buildings through the PLC. The database functions as a memory to store the command received (Bingol, et al., 2014).

2.3 Reduce environmental impact

An increase in electrical consumption will cause some impact on the environment as almost 90% of the energy is generated by the combustion of fossil fuels. This will increase the emission of greenhouse gases which cause a lot of harm towards the society (Madsen, 2008).

The construction and the material used for smart home is also a key for the reduction of environmental impact. One of the method is via the colour of the roof

installed. Use of lighter-coloured, compares to darker-coloured roof. Roof can actually lower the building temperature as lighter-coloured roof does not absorb as much heat. By installing windows in two different sides of the building helps in the air flow and cross ventilation, thus helping to reduce energy used. At the same time, this arrangement allows maximum light to enter the building so that the building are bright enough without switching on the light. The material used can be a factor as well. It is important to use non-heat absorbing and transmitting materials to reduce the heat being transmitted into the building. The smart residential buildings can be installed with green power source, such as wind and solar energy, to reduce the work load of the power grid. Green power source is renewable, and does not emit much greenhouse gases as the fossil fuels, therefore it can reduce the impact towards the environment. The power generated can be used for the purpose of heating up water, and also for other uses when the demand reaches its peak value. (Abimaje, et al., 2013).

2.4 Wireless home automation system

The home devices or appliances of a smart home can be controlled efficiently and remotely with wireless networks. There are a few different types of technologies which are used for this network system such as Z-Wave, Insteon, Wavenis, Bluetooth, WiFi and also Zigbee. These technologies allow the owners to monitor their home via surveillance camera, to turn on or off their home appliances even if they are not around their house. The network technologies also allows the owners to access to their home appliances information online, for example the power usage (John Robles & Tai-hoon , 2010). Among all the listed technologies, Zigbee has been widely used in smart residential buildings.

The Zigbee technology is widely used due to its high reliability with low maintenance. Besides the lower installation cost, the stability of this wireless technology are also higher as compare to other wireless networks. The power consumption of Zigbee is also low hence it will not drain too much power when it is

in used (Ni, et al., 2013). The Table 2 summarise the benefit of using Zigbee as compare to Bluetooth gateway.

Table 2-1: The comparison between two wireless gateways (Ni, et al., 2013)

Gateway	Network Stability	Anti-interference	Flexibility	Cost
Wi-Fi-Bluetooth gateway	Low	Bad	Bad	High
Wi-Fi Zigbee gateway	High	Good	Good	Low

Besides the wireless control system, voice control system is also widely used in smart residential buildings. This system not only bring benefits to the youngsters, but at the same time able to help elderly and also disabled people. The system model are shown in Figure 2.4

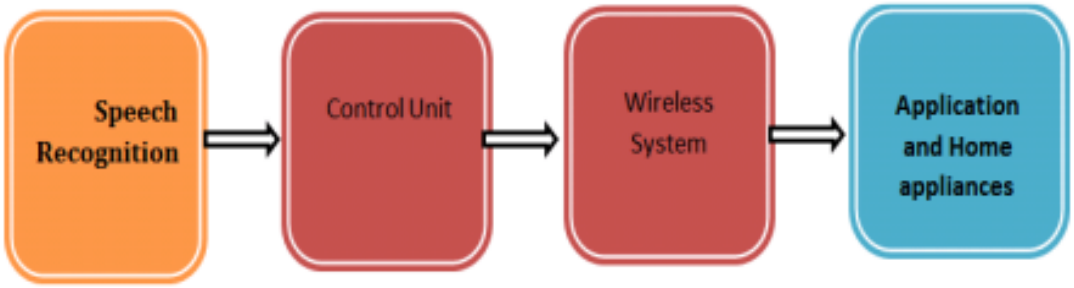

Figure 2.4: The system model (Obaid, et al., 2014)

This system allows user to control their intelligent home appliances by using voice commands. The system operates by receiving the voice command from the users and then interpret the received data in order to extract the required information and send the information to the home devices through the wireless network. A voice recognition is also implemented into this system so that only the user are able to take control over the home appliances. The system are able to recognize the voice through computer. A control unit component manages the activities within a computer such as the flow of the direction of information (Obaid, et al., 2014)

2.5 Ability of elder people to stay independently

Smart residential buildings are able to provide a living environment that allows elderly to stay independently without their family around and being sent to adult care facility. It also provides a comfortable and secure place for the elder to stay. In order to achieve this, certain technologies are being installed or used in the smart residential buildings.

One of the technologies is the emergency button. The buttons can be installed in the common places that are easily accessible or where the elderly spend most time. When the button is pressed during any emergency event, a signal will be transmitted to the relevant parties such as hospital or family members. Installation of smart residential buildings security, such as windows and doors with alarm, provides a more secure home the elderlies. The instalment of security camera allows notification of any intrusions by unwanted parties. A live feed can be transmitted to the family members allowing them to observe conditions of the home and surroundings. The smart residential buildings system is also able to supply the users with reminders to switch off electronics appliances and close the doors. It is also able to provide reminder to the elderlies to take their medicines on time (Qin Ni, et al., 215).

2.6 Benefits of smart metering

The instalment of smart meter has actually bring users some benefits. Figure 2.5 shows the different structures between a conventional energy meter and a smart meter system.

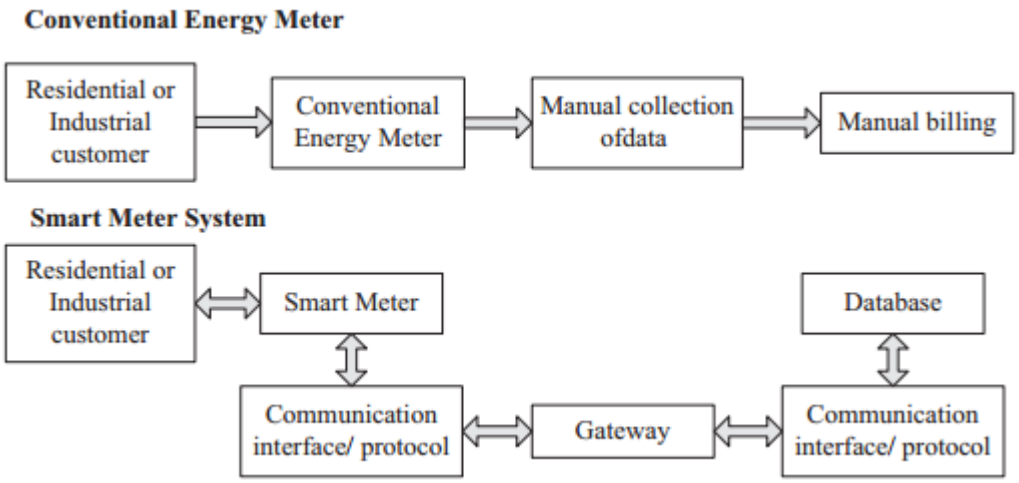

Figure 2.5: Metering architectures for conventional and smart meters (Wang, et al., 2011)

Smart meter system consists of communication interface, gateway, and database. These features allow smart meter to communicate bidirectional. The gateway allows data to be obtained via internet instead of manually. The smart meter is able to collect instantaneous total energy consumed, instead of total energy supplied, to provide a more accurate billing. It is much more convenient compare to conventional energy meter system whereby the billing amount of an estimated values.

The accurate data collection allows the energy company to further interpret electricity usage so as to provide advice on energy saving method for the consumers. This gateway also allow the smart meter to be integrated with the smart home systems to control the home appliances. Integrity of the home devices also helps for the detection of unauthorized usage or electricity theft (Wang, et al., 2011). Using smart meter clearly help in energy reduction, a study of this had been carried out by comparing smart meters and load controllers.

Table 2-2: Comparison of electrical consumption between smart meter, load controller and without any management technology (Torriti, 2014)

Floor	Demand side management technology	Electricity consumption in kWh	Number of peak events (over 0.8kWh for 3 employees)	Price (flat tariffs) in Euros	Price (Time-of-Use tariffs) in Euros
Ground	None	1318.2	15	116.71	132.14
1st	Smart Meter	969.1	2	81.89	87.89
2nd	Load Controller	1041.7	1	88.02	84.91

2.7 Attitude towards smart residential buildings technologies

2.7.1 Privacy of users

It is the most concern issue for smart residential buildings to be afraid of their personal data or daily activities leak out to an unknown persons. Most of the smart home appliances are able to communicate between one and another and also receive command from user through Internet, Bluetooth and etc. All these cause the smart residential buildings to be vulnerable to the hacker as they can use these as the access point to extract daily schedule and personal data of the resident (Demiris, et al., 2004). One of the example is that the hackers are able to observe the conditions and activities of the home by hacking into their video monitoring system and reprogrammed the system so that they can observed the house in real time (Kumar & R. Patel, 2014). Other than hacker, there might be a possibility that the data loss is due to the technical issues or carelessness of users. All the information about their home condition will be send to their smart devices and loss of these smart device will post a privacy threats to them and their family because home information is exposed to anyone who has picked up the smart device.

2.7.2 Trust of users towards smart residential building technologies

It is one of the challenging issue raise from user perspective as they do not have the trust towards the technologies that has been installed. Users are worry that the technologies cannot function during the time of crisis. Smart residential building is not only designed for youngsters but also for elderly and physically disorder group of people. Therefore it is important that the technologies can function at all-time such as sending of the emergency situation to family member's smart devices to notify their emergency needs. Other than the stated reason above, user's lack of trust towards smart residential building can be due to malfunctions of the system. One of the example is sending of a false alarm that causes everyone to be unease at that moment (Demiris, et al., 2004).

2.7.3 Usability and training

The instalment of advance technologies in smart home raise the complexity of the home. Users are required to gain some knowledge on how to operate those technologies within the building in order to have a comfortable living environment. This will make the novice users unease as they have to learn in order to live in smart home. Not all groups of people are exposed and are expert towards these technologies, some users will have the difficulties to learn all these new knowledge, causing their bad impressions of them towards the idea of smart residential building as they find difficulties and troublesome to live in such environment (Demiris, et al., 2004).

2.8 Limitations of Wireless Sensor Networks

There are some limitations on the usage of wireless sensor networks. Although the power consumption for an individual sensor node is relatively small, but the large number of sensor nodes required, to increase the coverage and accuracy of the network, increases the total power consumption. Besides, the power consumption of the nodes increase when the distance of the sensors from the base station increase.

The base station are the destination where the data collected from the sensors are sent. Another limitation arise as all these nodes can actually be used as a router to communicate and exchange the information gathered with other sensor nodes. This has actually opened up a great opportunities for the hackers to hack into the network. The vulnerability further increases due to the distribution of the sensors across a large area (Bhattacharyya, et al., 2010).

The size of the wireless sensor nodes also post several limitations. The type of power source being used is battery with limited power rating to prevent damage to the sensor. The limited powers from the batteries will be used up eventually and will need to be changed frequently. Since a large amount of sensor nodes are installed in a wireless sensor network, it is therefore very troublesome to locate the exact battery of the sensor which required a replacement (Potnis & , 2015). Another restrictions of this wireless sensor network is due to its storage for the purpose of security. In order to increase the security, a few cryptographic key is being installed in the sensor. The large amount of sensor node used causes a shortage of storage as it needs to store a few types of the cryptographic key in a single sensor node (Chelli, 2015). Wireless sensor networks also transmit data slower as compare to a wired network. Besides, the data that is being transmitted is easily affected by the surrounding conditions since it is transmitted via a wireless network. The data might be blocked, reflected by walls or lost due to attenuation (Bhattacharyya, et al., 2010).

2.9 Threats

The threats that smart residential buildings are due to human's acts. This group of people tend to eavesdrop, intercept, or hijack those data or information of the residents through the sensors or surveillance cameras; thus, allowing them to observe the activities of the resident. They can also hijack to the network, alter the information or create some false alarm to the user. They can also intercept the information that are supposedly send to the appliances, and take control on some of the smart home system such as lighting control system and climate control system;

causing inconveniences or posting threats to the security of the resident (Arabo, 2015).

2.10 Complaints of using smart technologies

The installation costs for the smart technologies are not cheap. However the major concern is on the impacts of the emission of radio frequency and electromagnetic wave from these technologies and meter.

Some of these technologies, such as the smart meter and wireless transmission, are often never switched off. The continuous usages of cause continuous emissions of electromagnetic waves and radio frequencies that actually cause harm towards human health. This is because that the users in the smart residential building are exposed to the wave for the period of time they spend at their home. The wave that is being transmitted can also come be emitted from the smart meter or technologies which are used by their neighbour. Smart meter can actually generate radiation power of 19.8 microwatts/cm2 and it only required 0.05 microwatts/cm2 to actually harm children. Some of the symptoms which will occur due to long period of exposure are as shown in the Figure 2.6:

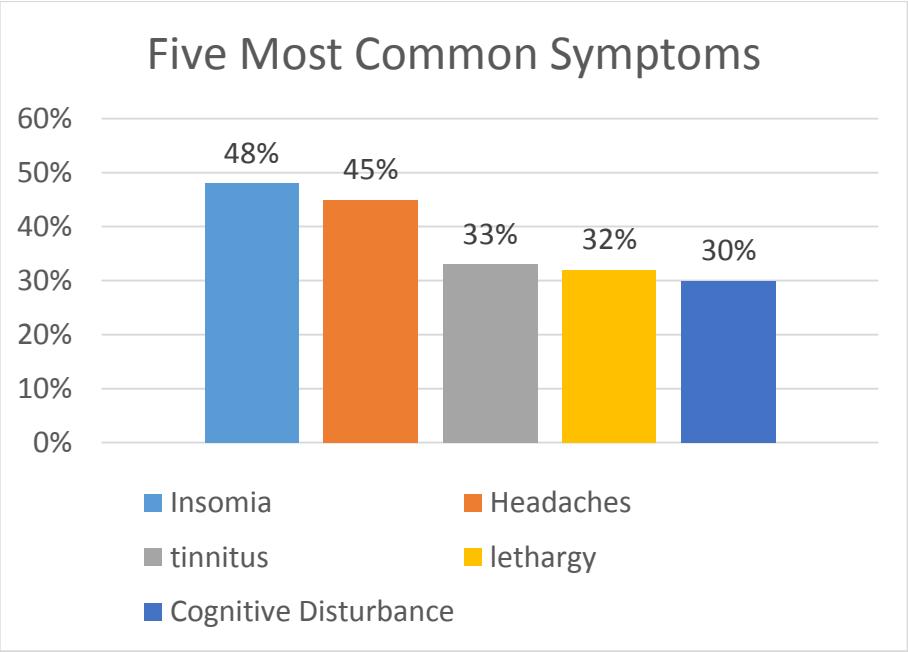

Figure 2.6: Five Most Common Symptoms (Worthington, 2015)

Besides the above mentioned symptoms, there are some more severe cases. These waves can also affect the functions of human body, people will tend to lose focus and also learning inability. Other than that, it will also affect reproductive organ causing infertility. This continuous exposed of radio frequency and electromagnetic wave will harm human up to the cellular level. It will cause cell death or damage. A serious side effect of the cells death is the reduction in immune systems. People will easily get sick and in the worst case scenario, users might get cancer (Worthington, 2015).

2.11 Summary

There are a few listed impacts in this chapter which are energy efficiency, reduce environmental impact, wireless home automation system, ability of elder people to stay independently, benefits of smart metering, attitude towards smart residential buildings technologies, limitations of wireless sensor networks, threats, as well as the complaints of using smart technologies. Among these listed impacts, one of the impacts is selected for further investigation. The impacts that has been selected will

be the complaints of using smart technologies. The method used for further investigation will be stated in Chapter 3 of the project.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter is about the method used to study on the impacts of smart residential buildings which have been investigated and listed in Chapter 2 of the project. The investigated impacts of smart residential building towards modern society are energy efficiency, reduce environmental impact, wireless home automation system, ability of elder people to stay independently, benefits of smart metering, attitude towards smart residential buildings technologies, limitations of wireless sensor networks, threats and also complaints of using smart technologies. The impact that has been selected for further discussion will be complaints of using smart technologies.

There are a few milestone in order for the objectives of this project to be achieved. The first milestone for the objectives is to investigate all the possible impacts of smart residential buildings towards modern society. This has been done in Chapter 2 of this project. The other milestones for this project is to carry out further investigation on the impacts of using smart technologies. One of the smart technologies that's been installed within the smart residential building is smart meter. There has been complaint raise from residents that by using smart meter actually caused health problems to them but without any solid prove. In order to investigate further, another milestone has been raise up for this project. That is to find and to study the suitability of formula and software required for this investigation. The last milestone required is the documentation of this project.

3.2 Complaints of using smart technologies

There have been complaints raise by the residents ever since they start to expose themselves to smart meters. The types of health problems that the residents suffer are insomnia, headaches, tinnitus, lethargy, and cognitive disturbance. However, there isn't any detailed investigation that's been carry out on this particular scope. Therefore in this project, the effect of the emitted radiofrequency (RF) from smart meter towards the health of human body will be further investigate. The method that will be used to study this is through concept of Specific Absorption Rate (SAR).

3.2.1 Specific Absorption Rate

Smart meters communicates with utility company, smart appliances at home and consumer by using wireless communication network. There are mainly two types of wireless network technologies that's been used by smart meter for communication purpose. The technologies used are Zigbee and KNX-RF which uses radiofrequency (RF) to transmit information from the transmitter to the receiver (S., et al., 2016).

Specific Absorption Rate (SAR) is actually the time rate at which electromagnetic energy which been absorb in a biological tissue. This Specific Absorption Rate (SAR) had been used in some research such as to study how smart phone will affect human body health (Adheed Hasan Sallomi, 2012) and some research had been carried out by comparing the radiofrequency emit from smart phone and smart meter. There isn't any research carry out by comparing the between the types of energy meters In this research, this Specific Absorption Rate is used to compare between smart meter, automatic meter reading (AMR) and also conventional meter to see which meter used by resident will have the highest impact towards them. The formula of Specific Absorption Rate (SAR) are as follow (Moradi, et al., 2016):

$$SAR = \frac{\sigma {E_{rms}}^2}{\rho} \qquad 3\text{-}1$$

σ: Specific conductivity, S m^{-1}

E^2_{rms} : Effective amount of field in tissue, V m^{-1}

ρ: Density of radiation-exposed tissue, gr cm^{-3}

The reading of radiofrequency emitted from smart meters and conventional meters had been measured by using Axis RF Field Strength Meter whereas the value of radiofrequency emitted from automated meter reading had been obtained through other research. The measured radiofrequency value for smart meter is 0.0014W/m^2 and the value measured for conventional meter will be 0.000057W/m^2. The type of model of this meter used will be TM-195 and the specification of this model will be listed in appendix of this report. There aren't any measured values of radiofrequency strength for automated meter reading (AMR) and the reading is taken through online research. The obtained value of radiofrequency strength for automatic meter reading (AMR) is 0.0012mW/cm^2 (Bodnar, 2012).

The tissues cells that human body will exposed to this radiofrequency including nerve, brain, and eye (A K M , et al., 2013). Different types of tissue cell will have different values of specific conductivity and density of radiation-exposed tissue. In this studies, brain will be chosen as it will cause the most severe damage to human body as compare to others body tissues. The Specific Absorption Rate (SAR) will be used to calculate and the results are generated through software problem such as Matlab. The results will be compare between smart meter, automatic meter reading (AMR), and conventional meter.

All the radiofrequency strength obtain from smart meters, automated meter reading, and conventional meter are converted into electrical field strength for calculation purpose by using field strength conversion table. The formula used will be (Anon., n.d.)

$$electric\ field\ \left(\frac{V}{m}\right) = \sqrt{377 x radiofrequency\ strength\ \left(\frac{W}{m^2}\right)} \qquad 3\text{-}2$$

where 377 represent the characteristics impedance of free space and air in ohm (Armstrong, et al., 2011).

3.3 Summary

This chapter covers the method use for further investigating the chosen impact from the listed impacts in Chapter 2 of this report. The chosen impact will be drawbacks of using smart technologies and smart meters. However only the investigation of the drawbacks of the smart meters are carry out. The results obtain through this method will be listed in Chapter 4 of this report together with further discussion based on the results obtained.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, it will shows the results obtain from the method shows in Chapter 3 which is used to investigate the selected impacts of smart residential buildings towards modern society. The selected impact is the complaints of using smart meters. This impacts has been studied by calculating the Specific Absorption Rate (SAR) and the results are used to compare between smart meter, Automatic Meter Reading, and conventional meter. Further discussion will be carry out base on the results obtained.

4.2 Specific Absorption Rate (SAR)

Specific Absorption Rate (SAR) is the time rate at which electromagnetic energy which been absorb in a biological tissue. The rate and distribution of radiofrequency (RF) energy absorption depend greatly on few parameters such as frequency, strength and orientation of the incident fields as well as the body size, and its constitutive electrical properties (Anon., 2015). The values of radiofrequency strength emitted from all three types of the meters, and the values of electric field are shown in the table below:

Table 4-1: Types of meters and radiofrequency strength

Types of meters	Radiofrequency strength	Electric field (V/m)
Smart meter	0.0014W/m^2	0.73
Automatic Meter Reading (AMR)	0.0012mW/cm^2	2.13
Conventional Meter	0.00052W/m^2	0.44

The values of electric field shown in the table above will be substitute into the formula used to calculate for Specific Absorption Rate (SAR). The formula is as shown:

$$SAR = \frac{\sigma {E_{rms}}^2}{\rho} \qquad 4\text{-}1$$

The part that is selected for the calculation of Specific Absorption Rate (SAR) will be head tissue. σ represent the specific conductivity for head limp with value of 1.79 S m^{-1} while ρ represent the density of radiation-exposed tissue for head with a value of 1.027 gr cm^{-3} (Moradi, et al., 2016).

The calculated Specific Absorption Rate (SAR) for different types of meters are as shown:

Table 4-2: Types of meters and Specific Absorption Rate (SAR)

Type of meters	Specific Absorption Rate (SAR) W kg^{-1}
Smart meter	0.9288
Automatic Meter Reading (AMR)	7.9075
Conventional meter	0.3374

The result obtained is then simulated by using Matlab software. The following figure shows the simulated results.

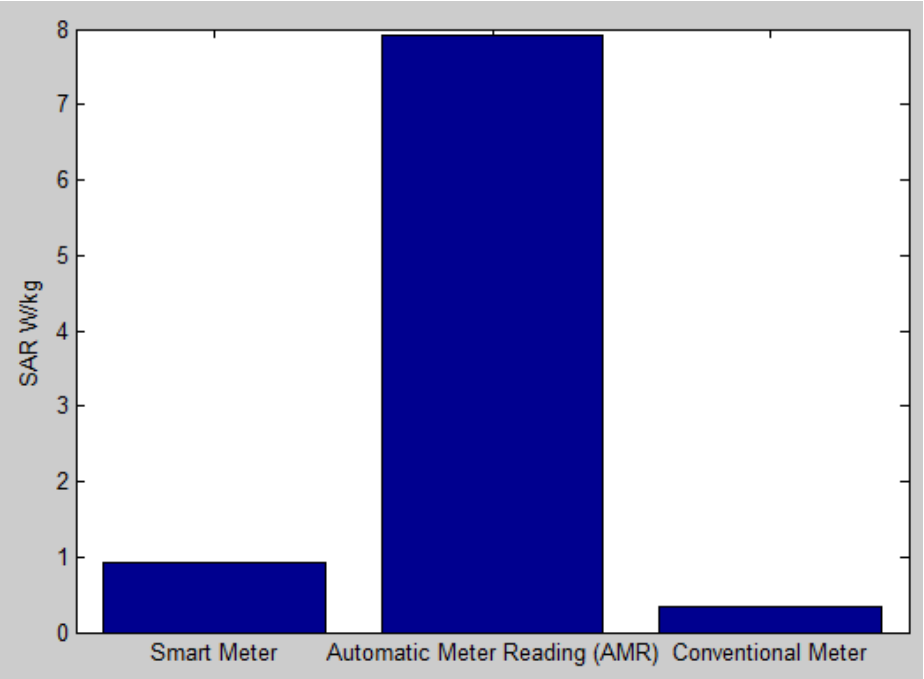

Figure 4.1: Types of meters and Specific Absorption Rate (SAR)

Based on the bar graph above, it can be observed that the highest values of Specific Absorption Rate (SAR) calculated will be Automatic Meter Reading (AMR) with the value of 7.9075W kg^{-1}, follow by smart meter with values of 0.9288W kg^{-1}, and lastly will be conventional meter with the value of 0.3374W kg^{-1}. This shows that Automatic Meter Reading (AMR) will bring the greatest health impact and conventional meters bring the least health impact towards the society.

The selection of the above meters are based on the evolution of energy meter. Conventional meter that is still been widely used in residential area are first develop in the 19^{th} century. One of the example of conventional meter is electromechanical meter. Energy meter has been evolve with the advancement of science and technology in order to provide a higher accuracy in energy data collection. The next energy meters that's been used is automatic meter reading (AMR). This meter consists of additional features which allows remote reading of the energy data from utility company. It uses communication link which transmit data wirelessly. Smart meter represent the newest technology used, it also consists of the same feature as automatic meter reading (AMR). However, there's additional feature being added to this meter that not only allows it to communicate the data information to utility

company or consumer, it can also provide control over the smart devices that's been installed within the smart residential building (Harney, 2009).

4.3 Radiofrequency Emission

Radiofrequency radiation is also known as electromagnetic radiation. This electromagnetic radiation can be categorized into two groups, which are ionizing and non-ionizing radiation.

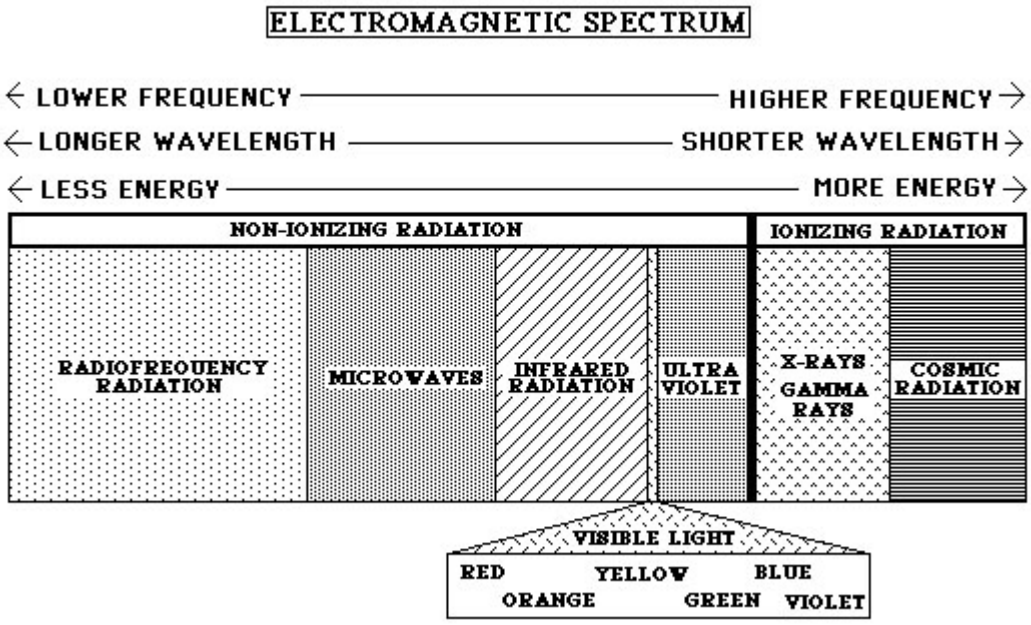

Figure 4.2: Electromagnetic Spectrum (Ciprazo, n.d.)

Ionizing radiation is a type of electromagnetic wave that contain sufficient energy to isolate electron from an atom. Since ionizing radiation consists of higher energy as compare to non-ionizing radiation, therefore it is more dangerous to human. When human cells are ionized, 3 things will occur which are the death of the cells, the cell will repair on its own or it cause the cell to mutates incorrectly which lead to formation of cancer cells (H.M., n.d.).

The types of radiofrequency emission from the meters are compose of non-ionizing radiation, which does not cause critical harm as compare to ionizing radiofrequency radiation. However, this does not mean that it will not cause any harm towards human body. Long exposure of this non-ionizing radiation will cause certain some biological effects on human body. The possible biological effects of non-ionizing radiation will be shown in the table below.

Table 4-3: Biological Effects of Different Non-Ionizing Radiations (Kwan-Hoong , 2003)

	Wavelength, frequency	Biological Effects
UVC	100 nm	Skin – Erythema, inc pigmentation
	280 nm	Eye – Photokeratitis (inflammation of cornea)
UVB		Skin – Erythema, inc pigmentation
		Skin cancer
	315 nm	Eye – Photochemical cataract
		Photosensitive skin reactions
UVA		Skin – Erythema, inc pigmentation
	400 nm	***Skin photo-ageing, Skin cancer***
Visible		Eye – Photochemical & thermal retinal injury
	780 nm	Eye – Thermal retinal injury
IRA		Eye – Thermal retinal injury, thermal cataract
	1.4 μm	***Skin burn***
IRB		Eye – Corneal burn, cataract
	3 μm	***Skin burn***
IRC		Eye – Corneal burn, cataract
	1 mm	Heating of body surface
Micro-wave	300 GHz	Heating of body surface
	1 GHz	Heating with 'penetration depth' of 10 mm
		Raised body temperature
	<100 KHz	Cumulation of charge on body surface
		Disturbance of nerve & muscle responses
Static	0 Hz	Magnetic field – vertigo/ nausea
		Electric field – charge on body surface
Long-term effects are given in italics.		

4.4 Conclusion

This chapter provides the answer based on the method mention in Chapter 3 of this report. There are a total of three different types of meters that's been chosen for further investigation in this chapter.

The radiofrequency strength emit are different based on the types of meters used. The radiofrequency strength for both smart meter and conventional meter has been measured by using Axis RF Field Strength Meter while the values of automatic meter reading is obtain through other research paper. Three of the meters are used to calculate the Specific Absorption Rate (SAR) which are the method mention in Chapter 3 to carry out further investigation on the impact of drawbacks of smart meter. The calculated results shows that automatic meter reading consists of the highest values, follow by smart meter, and lastly will be conventional meter. This result shows that automatic meter reading caused the greatest harm, and conventional meters will have the least health impact towards human body.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter conclude the analysis and discussion of the results obtained from Chapter 4 of this report. Recommendation will be provided in this chapter of the report. A further investigation based on the recommendation might be required in the future work.

5.2 Research Conclusion

Among the investigated possible impacts which has been listed in Chapter 2 which is the literature review in this report, one of the impacts of smart residential buildings towards modern society had been selected for a detailed investigation.

The selected impacts is the complaints of using smart technologies. The smart technologies includes smart blub, thermostat, smart security, voice-base technologies and smart meter. Among all these smart technologies, only the complaints about smart meter is selected for a detailed investigation. The method used to investigate this impact is through Specific Absorption Rate (SAR). There will be few parameters which will affect the values obtained for this Specific Absorption Rate (SAR) such as the radiofrequency strength, the specific conductivity, density of radiation-exposed tissue, and effective amount of field in the tissue. However, the parameters for

specific conductivity and density of radiation-exposed tissue is fixed by selecting the head tissue, and this cause the only variable parameters will be the effective amount of field in the head tissue.

The effective amount of field in the head tissue will be directly affected by the radiofrequency radiation emit from the meters. By substitute the collected data into the formula for Specific Absorption Rate (SAR), it is observed that automatic meter reading produce the greatest values of Specific Absorption Rate (SAR) while conventional meter produce the lowest values of Specific Absorption Rate (SAR). Although smart meter does not produce much harm towards human as compare to automatic meter reading, but it cause greater harm to human health as compare to conventional meter.

5.3 Research Recommendation

The research recommendation that will be provided in this research is the implementation of energy generating tile into smart residential building to study the impact of this towards the modern society.

This energy generating tile is also known as smart tile. It is made of piezoelectric material which will produce electricity when there is an external force compress against it (Siddappa D & Ahmed, 2016).

REFERENCES

A K M , F. H., Hossain, M. S., M. A. & A. S. M., 2013. A study on specific absorption rate (SAR) due to non-ionizing radiation from wireless/telecommunication in Bangladesh. *American Journal of Physics and Applications*, l(3), pp. 104-110.

A. H. S., 2012. A Theoretical Approach for SAR Calculation in Human Head Exposed to RF Signals. *Engineering and Development,* 16(4), pp. 304-313.

A., J. & A., 2013. Energy Efficient Housing as a Mitigating Option for Climate Change in Nigeria. *International Journal for Energy and Environmental Research*, Volume 1, pp. 16-22.

Anon., 2008. *Energy Efficiency Trends in Residential and Commercial Buildings.* [Online]
[Accessed 15 April 2016].

Anon., 2015. *LIMITS OF HUMAN EXPOSURE TO RADIOFREQUENCY ELECTROMAGNETIC ENERGY IN THE FREQUENCY RANGE FROM 3KHZ TO 300GHZ.* [Online]
Available at: http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/consult/_2014/safety_code_6-code_securite_6/final-finale-eng.pdf
[Accessed 26 August 2016].

Anon., n.d. *eia.* [Online]
Available at: http://www.eia.gov/electricity/
[Accessed 20 June 2016].

Anon., n.d. *Powerwatch.* [Online]
Available at: http://www.powerwatch.org.uk/science/unitconversion.asp
[Accessed 23 August 2016].

Anon., n.d. *SMART BUILDING TECHNOLOGIES.* [Online]
Available at: http://www.smartbuildingtec.com/our-history/
[Accessed 15 April 2016].

Anon., n.d. *TENMARS.* [Online] Available at: http://www.tenmars.com/webls-en-us/TM-195.html [Accessed 24 August 2016].

Arabo, A., 2015. Cyber Security Challenges within the Connected Home Ecosystem Futures. *ScienceDirect,* pp. 227-232.

Armstrong, B. et al., 2011. *Non-ionizing Radiation, Part 2: Radiofrequency Electromagnetic Fields.* Lyon: International Agency for Research on Cancer.

Attia, I. I. & Ashour, H., n.d. Energy Saving Through Smart Home. *The Online Journal on Power and Energy Engineering,* Volume 2-3, pp. 223-227.

Bangali, J. & Shaligram, A., 2013. Energy efficient Smart home based on Wireless Sensor Network using LabVIEW. *American Journal of Engineering Research,* 2(12), pp. 409-413.

Bhattacharyya, D., Tai-hoon, K. & Pal, S., 2010. A Comparative Study of Wireless Sensor Networks and Their Routing Protocols. *Sensors 2010,* Volume 10, pp. 10506-10523.

Bingol, O., Tasdelen, K., Keskin, Z. & Emre Kocaturk, Y., 2014. Web-based Smart Home Auotmocation: PLC- controlled Implementation. 11(3), pp. 51-63.

Bodnar, M., 2012. *AUTOMATED METER READING (AMR) ELECTRIC.* [Online] Available at: http://www.penticton.ca/assets/Departments/Documents/AMR%20Information%20Sheet.pdf [Accessed 20 August 2016].

Chelli, K., 2015. Security Issues in Wireless Sensor Network Attacks and Countermeasjres. *Proceeding of the World Congress on Engineering 2015,* Volume 1.

Ciprazo, E., n.d. *Berkeley EH&S.* [Online] Available at: http://ehs.berkeley.edu/laser-safety/non-ionizing-radiation-safety-manual [Accessed 23 August 2016].

Cone, B., n.d. Will I really be able to save money and energy in the long run by shelling out hundreds of dollars now for a so-called “smart” thermostat?. *Adventure Sport Journal.*

Demiris, G. et al., 2004. Older adults' attitudes towards and perceptions of 'smart home' technologies: a pilot study. *Medical Informatics,* 29(2), pp. 87-94.

H.M., D., n.d. *Physics Central.* [Online] Available at: http://physicscentral.com/explore/action/radiationandhumans.cfm [Accessed 23 August 2016].

Harney, A., 2009. Smart Metering Technology Promotes Energy Efficiency for a Greener World. *Analog Dialogue* .

John Robles, R. & Tai-hoon , K., 2010. Applications, Systems and Methods in Smart Home Technology: A Review. *International Journal of Advanced Science and Technology,* Volume 15, pp. 37-48.

Kumar K, S., P, P., Jose, G. K. & G, B., 2015. Human Detection Robot using PIR Sensors. *International Jounal of Science, Engineering and Technology Research,* 4(3), pp. 492-496.

Kumar, J. S. & R. Patel, D., 2014. A Survey on Internet of Things : Security and Privacy Issues. *International Journal of Computer Applications,* 90(11), pp. 20-26.

Kwan-Hoong , N., 2003. *Non-Ionizing Radiations - Sources, Biological Effects, Emissions and Exposures,* s.l.: s.n.

Madsen, J. J., 2008. Intelligent Building are Green, Too. *Improve building performance, streamline facilities management, and reduce your building's impact on the environment with intelligent building technologies,* 08 01.

Moradi, M. et al., 2016. Effects of the Effect of Ultra High Frequency Mobile Phone Radiation on Human Health. *Electron Physician,* 8(5).

Ni, Y., Miao, F., Liu, J. & Chai, J., 2013. Implementation of Wireless Gateway for Smart Home. *Communication and Network,* Volume 5, pp. 16-20.

Obaid, T. et al., 2014. Zigbee Based Voice Controlled Wireless Smart Home System. *International Journal of Wireless & Mobile Networks,* Volume 6, pp. 47-59.

Potnis, A. & C. S. R., 2015. Wireless Sensor Network: Challenges, Issues and Research. pp. 224-228.

Q. N., A. B. G. H. & I. P., 215. The Elderly's Indeoendent Living in Smart Homes: A Characterization of Activities and Sensing Infrastructure Survey to Facilitate Services Development. *Sensors 2015,* Volume 15, pp. 11312-11362.

S.M., S., T.M.I, M. & A., A., 2011. Current energy usage and sustainable energy in Malaysia. *SciVerse Science DIrect,* pp. 4370-4377.

S., O. et al., 2016. Radiofrequency Interconnection between Smart Grid and Smart Meters Using KNX-RF and 2,4GHz Standard Protocols for Efficient Home Automation Applications. *Journal of Communications,* Volume X.

San Martin, J. et al., 2011. Energy Storage Technologies for Electric Applications. pp. 1-6.

Shubha, P., S, A., P, L. & Rao, V. C., 2015. Wireless residential lighting control and Home securiy for real time application. *International Journal of Electrical, Electronics and Computer Systems,* 3(1), pp. 2347-2820.

Siddappa D, S. & Ahmed, S. A., 2016. Design and Analysis of Power Generating Tiles. *Ird India,* IV(1), pp. 2321-5747.

S. S. S. R. D., Wang, L. & Devabhaktuni, V., 2011. Smart meters for power grid: Challenges, issues, advantages and status. *Renewable and Sustainable Energy Reviews,* 15(6), pp. 2736-2742.

Swarnalatha, P., M.Rajasekhara, B. & Surendhar, T., 2011. Building Management System Using Windows Comminication Foundation and XAML. *Internation Journal of Engineering and Technology,* Volume 3, pp. 95-99.

Torriti, J., 2014. People or machines? Assesing the impacts of smart meters and load controllers in Intalian office spaces. *Energy for Sustainable Development,* pp. 86-91.

Worthington, A., 2015. Smart Meters-not so Smart. *How Dangerous and Expensive Became "Smart" An Expose of the "Smart Grid"*, 19 January.

Ylä-Jarkko, M., 2016. *Cubic volume covered by granted building permits increased in December to February.* [Online] Available at: http://tilastokeskus.fi/til/ras/2016/02/ras_2016_02_2016-04-22_tie_001_en.html?ad=notify [Accessed 20 June 2016].

Y. P. & F. S. U., 2014. Windows Communication Foundation for Banyumas Tourism and Culinary Information System. 12(4), pp. 1031-1038.

Zipperer, A. et al., 2013. Electric Energy Management in the Smart Home: Perspective on Enabling Technologies and Consumer Behavior. *National Renewable Energy Laboratory,* Issue August, pp. 1-10.

APPENDICES

APPENDIX A: Axis RF Field Strength Meter

Axis RF Field Strength Meter is used for the measurement of the radiofrequency strength emit from smart meter, and conventional meter. The model number for this type of meter will be TM-195.

This model is designed to measure and to monitor radiofrequency (RF) electromagnetic strength. It is able to measure frequency range from 50MHz – 3.5GHz. The specification of the model is shown in the table below.

Table 5-1: Specification of TM-195 (Anon., n.d.)

Display type	Liquid-crystal (LCD), 4-1/2 digits maximum reading 19999
Measurement method	Digital triaxial measurement
Directional characteristic	Isotropic, triaxial
Measurement range selection	One continuous range
Display resolution	0. 1mV/m, 0.1μA/m, 0.001μW/m2, 0.001μW/cm2
Setting time	Typically 1.5s (0-90% measurement value)
Sample rate	1.5 times per second
Audible alarm	Buzzer
Units	mV/m, V/m, μA/m, mA/m, μW/m2, mW/m2, μW/cm2
Display value	Instantaneous measured value, maximum value, average value, or maximum average value

Alarm function	Adjustable threshold with ON / OFF
Calibration factor CAL	Adjustable
Manual data memory and read storage	200 data sets
Batteries	9V NEDA 1604, IEC 6F22 or JIS 006P
Auto power off	Default time 15 minutes. Adjustable threshold 0~99 minutes
Operating temperature range	0°C to + 50°C
Operating humidity range	25% to 75% RH
Storage temperature range	-10°C to +60°C
Storage humidity range	0% to 80% RH
Dimensions	60(L)*60(W)*195(H) mm
Weight (including battery)	Approx. 200g
Accessories	User’s manual, 9V battery, carrying case