In-Home Displays: Factors Influencing Consumer Receptivity

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A dissertation submitted to the University of Dublin in partial fulfilment of the requirements for the degree of MSc in Management of Information Systems

1st September 2014

Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work, and has not been submitted as an exercise for a degree at this or any other university. I further declare that this research has been carried out in full compliance with the ethical research requirements of the School of Computer Science and Statistics.

Signed: ____________________

Frederick Dietei Ikoli

1st September, 2014

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Acknowledgements

I would like to express my sincere gratitude to my supervisor Paula Roberts for her invaluable support, guidance and encouragement throughout the process of completing this dissertation.

I would also like to thank my friend and work colleague Phil Hughes for his support, for which I am extremely grateful. I would like to express my sincere appreciation to the survey participants for sparing a few minutes of their time to complete the survey.

It gives me immense pleasure to thank my siblings and parents-in-law for their words of encouragement while carrying out my research.

Above all, my deepest gratitude goes to my wife: Gloria and my children: Jason, Gwyneth and Nicole for their love, understanding and patience at all times; I am forever indebted to you.

Lastly, I dedicate this dissertation to the memory of my late parents, Frederick Binis Daniel Ikoli and Paulina Celestina Ikoli who instilled in me the values of hard work and perseverance from an early age. God bless your souls.

Abstract

As the cost of energy rises dramatically across Europe and the rest of the world, coupled with growing concerns about climate change, it is imperative that households adopt technological solutions that will monitor and help reduce their energy use. In-home displays (IHDs) measure energy use and cost in real-time allowing consumers to visualise, understand, analyse, and improve their energy consumption. However, their uptake has been slow despite desperate efforts by consumers to seek ways to escape high energy bills even as energy prices continue their generally upward spiral. This research determines the factors that influence consumer receptivity to IHDs and the extent to which demographic variables moderate their influence.

A research model customised from UTAUT2 (Venkatesh et al., 2012), to best fit in the context of consumer receptivity to IHDs, was used to formulate the hypotheses tested in an attempt to address the research question. An online survey was adopted as the research strategy primarily for its ubiquity. The survey revealed interesting and surprising data that provided new insights into the extent to which demographic variables moderate the effect of the factors that influence consumer receptivity to IHDs.

This study provides statistical evidence that indicates that the following all influence consumer receptivity to IHDs: performance expectancy, effort expectancy, price value, aesthetics design, facilitating conditions and resistance to lifestyle change. The findings of this study show that their effects (with the exception of price value and facilitating conditions) are moderated by familiarity and/or age. Arguably, resistance to lifestyle change is the most problematic; this poses a great challenge to energy efficiency measures targeting behaviour change. Therefore, the immediate focus of most energy efficiency initiatives should be on finding ways to encourage consumers to reshape their energy use behaviour following their interaction with feedback from IHDs. IHD is only a part of the solution; it is ultimately the consumers' responsibility to react to the feedback.

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Abbreviations

ACEEE	American Council for an Energy-Efficient Economy
AI	Artificial Intelligence
APMR	Arduino Power Meter Reader
AT&T	American Telephone & Telegraph
BCS	Behaviour Change Strategies
BPA	Bonneville Power Administration
BRE	Building Research Establishment
CEC	California Energy Commission
CER	Commission for Energy Regulation
CONSENSUS	Consumption Environment Sustainability
CSV	Comma-Separated Values
DECC	Department for Energy and Climate Change
Delta-ee	Delta Energy & Environment
DR	Demand Response
EDP	Energias de Portugal
EDRP	Energy Demand Research Project
EEA	European Environment Agency
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EP	Effort Expectancy
EPRI	Electric Power Research Institute
ERSC	Energetic Services Regulatory Entity
ESI	Energy Saver incentive
EST	Energy Saving Trust
EU	European Union
HEM	Home Energy Monitor
HEMS	Home Energy Management Systems
IBS	Intelligent Building System
ICT	Information and Communications Technology

IEA	International Energy Agency
IHD	In-Home Display
KW	Kilowatt
KWh	Kilowatt hour
MavHome	Managing An Intelligent Versatile Home
MIT	Massachusetts Institute of Technology
MySQL	My Structured Query Language
NAHB	National Association of Home Builders
Ofgem	Office of Gas and Electricity Markets
P2P	Peer to peer
PA	Personnel Administration
PC	Personal Computer
PDS	Premises Distribution Systems
PE	Performance Expectancy
PEOU	Perceived Ease Of Use
PU	Perceived Usefulness
SCS	Systimax Structured Cabling System
SQL	Structured Query Language
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TRON	The Real-time Operating system Nucleus
TV	Television
UK	United Kingdom
US	United States
UTAUT	Unified Theory of Acceptance and Use of Technology
VEET	Victorian Energy Efficiency Target
XLS	Excel

1 Introduction

There is growing concern among nations worldwide that the global increase in energy consumption is both economically and environmentally unsustainable. Many policymakers are focused on reducing the demand for energy, as studies have shown that global energy sustainability can be achieved cost effectively through demand reductions. Household energy consumption will account for 14 percent of the global energy use in 2040, rising by 57 percent from 2010 to 2040 (Energy Information Administration [EIA], 2013). Promoting the efficient use of energy, particularly electricity, is difficult, because unlike water, for example, electricity is intangible, invisible, and its use is part of everyday life (Hargreaves et al., 2010).

Economic measures, such as tariffs, pricing or energy efficiency labelling, have been implemented to influence residential energy consumption. However, the continuous increase in residential energy use suggests that an economic-based energy management approach has limited success in promoting residential energy conservation. As the cost of energy rises dramatically across Europe and the rest of the world, coupled with growing concerns about climate disruptions caused by carbon dioxide emissions, it is imperative that households adopt technological solutions that will monitor and help reduce their energy use.

Feedback on energy consumption has been extensively researched. Existing studies show that providing direct instantaneous feedback on household energy use can potentially reduce energy consumption by 4 to 13 percent (Ehrhardt-Martinez et al., 2010; Faruqui et al., 2010). Unfortunately, many homes in Ireland and around the world currently rely on the traditional monthly energy bill to understand their energy consumption, which does not provide fine-grained insight into energy consumption in the home. Home energy monitoring is available in the following three main categories:

1. Outlet monitoring: Smart plugs or power strips that measure how much energy individual outlets are consuming. Once plugged into an outlet, an appliance or device can be plugged into it; it will monitor and display the amount of energy consumed by the appliance or device.

2. Whole-house and appliance-level monitoring: In-home displays (IHD), also known as home energy monitors (HEM), provide convenient feedback on energy consumption and cost in real-time. This allows it to be visible to householders in a representation which is appropriate for decision making. This can generate positive net effects, such as a reduction of energy waste, consumer savings on energy bills,

and a reduction in peak demand, which in turn would allow utility companies to reduce the peak power generation capacity. IHDs offer a simpler, effective and affordable way to achieve residential energy efficiency though monitoring whole-house and appliance-level energy consumption.

3. Smart homes: Smart home technology monitors, controls and analyses energy use by enabling intercommunication amongst all household devices and appliances, thereby providing households with an excellent way to manage energy consumption, while maintaining a balance between energy saving and a comfortable lifestyle. Despite the benefits on offer, the uptake of smart homes has been slow, mainly due to the high price of smart appliances, installation and ongoing liabilities.

Like energy, water is also vital to health and quality of life, and its demand is on the increase. Water is necessary for energy development and production, and energy is needed for the distribution and treatment of water. Therefore, water and energy are inextricably connected, so saving water saves energy. However, there is a general lack of awareness among households about the tight-knit relationship between energy and water. Domestic water heating accounts for a significant portion of energy consumed in homes. Studies of household water usage revealed that showers, particularly power showers, use the most water in homes and contribute substantially to electric bills (Dufferin Research, 2013; Energy Saving Trust, 2013; Irish Water, 2013).

Research has shown that there is a direct correlation between household characteristics, lifestyle and energy use, and that behavioural changes offer the best hope for substantially reducing household energy consumption (Ehrhardt-Martinez et al., 2009). The first step towards energy conservation is to understand its consumption. As Management consultant, Peter F. Drucker famously once said in another context; “if you can’t measure it, you can’t manage it”. At a basic level, in-home displays measure energy use and cost in real-time allowing consumers to visualise, understand, analyse, and improve their energy consumption, which translates into cost savings on energy bills. Unlike smart home technology, IHDs are available at a reasonably affordable price. However, like smart home technology, their uptake has also been slow, despite desperate efforts by consumers to seek ways to escape high energy bills even as energy prices continue their generally upward spiral.

1.1 Objective and Scope of the Research

The scope of this research is limited to Information and Communication Technology (ICT) based energy efficiency solutions with a particular focus on standalone IHDs. It seeks to establish the factors that influence consumer receptivity to IHDs and their moderators with emphasis on electricity since electric energy is the most common source of energy used by households in Ireland.

1.2 Research Question

The research question to be addressed in this study is:

What are the factors that influence consumer receptivity to in-home displays?

In seeking to answer the research question, the following question was spawned:

To what extent, if any, do demographic variables moderate the effect of the factors that influence consumer receptivity to IHDs and potential to use IHDs?

1.3 Relevance of this Research

Tackling climate change is one of the greatest challenges facing the world today. The European Commission has outlined its proposals for climate and energy policies up to 2030, which demand a 40 percent reduction in carbon emissions by the year 2030, compared with 1990 levels. Energy efficiency is an important element of these policies and has proved to be one of the most cost-effective ways to cut carbon emissions and secure future energy supplies.

Energy efficiency initiatives in some EU countries, such as Ireland and the UK, involve the roll-out of smart meters, which will be complemented with IHDs. IHDs provide smart meter data to consumers in an easy-to-understand format, thus making energy consumption more visible. Direct feedback from IHDs motivates households to change their energy use behaviour, which translates into lower energy bills. In order for energy efficiency initiatives involving smart meters to generate the most value, it is important that these initiatives embrace consumers' energy-use behaviour and perceptions of IHDs, as success in achieving energy savings through smart meter roll-outs hinges on the active participation of consumers. Therefore, it is of the utmost importance that policy makers and, in particular, manufacturers of energy-saving devices, consider the factors that influence consumer receptivity to ICT-based energy efficiency solutions, such as IHDs.

1.4 Research Beneficiaries

This dissertation may be of interest to governments, utility providers, and IHD manufacturers. The findings of this research may be useful in developing and implementing government-led energy efficiency initiatives that involve the roll-out of smart meters complemented with IHDs. In Ireland, for example, the findings of this research could be useful to the Commission for Energy Regulation when outlining the minimum requirements that standard IHDs must meet to ensure an acceptable level of quality (Commission for Energy Regulation, 2012). The findings of this research could be used as a foundation for future studies of the key IHD ergonomic attributes that influence consumer acceptance.

1.5 Dissertation Roadmap

This dissertation is structured as follows:

Chapter 1 provides background information on the research area and introduces the research topic. This chapter discusses the objective and scope of the research, the relevance of the research, and the beneficiaries of the research.

Chapter 2 provides a review of the relevant literature related to the research. It discusses the effectiveness of IHDs, presents an overview of some IHD products and trends, and discusses some energy efficiency initiatives involving IHDs. The chapter also explains the inextricable link between water and energy and how this affects energy use. Mounting evidence in academic literature indicates that energy efficiency measures, which target consumer behaviour, have the greatest potential for reducing energy use; another important area also discussed in this chapter. The chapter also presents an overview of some models of technology adoption and concludes with a brief summary of the key points.

Chapter 3 describes the research methodologies considered to address the research question for this study. The chapter justifies the chosen research strategy, clearly identifies its drawbacks in relation to this study and explains the measures implemented to counter these drawbacks. It also describes the research design, explains the rationale behind the research method chosen and discusses some ethical considerations. Finally, the chapter presents the proposed research model for this study, and the hypotheses that will be tested as part of this research.

Chapter 4 presents, analyses and discusses the research findings from an online survey.

Chapter 5 highlights the findings of the quantitative study and briefly discusses how these findings answered the research question, linking them to the reviewed literature. It summarises the key points from this research, outlines recommendations based on the research findings and reviewed literature, acknowledges the limitations of this research and suggests directions for future research in this area.

2 Literature Review

2.1 Introduction

The purpose of this literature review is to critically analyse relevant published work on energy-saving technologies, with a particular focus on IHDs. This chapter reviews some definitions of a Smart Home by other researchers and presents a new succinct definition of a Smart Home. It explains the emergence of the Smart Home concept by exploring the historical emergence of the Smart Home concept and the history of domestic technology.

This chapter also presents a brief overview of several Smart Home research projects and findings in the area of energy efficiency, with some consideration given to comfort, entertainment, safety and security. It explores research carried out on the effectiveness of feedback technologies, in particular IHDs, and presents an overview of IHD products and trends.

The chapter discusses some initiatives by utility providers and governments, energy-related impacts of domestic water use, behavioural change in relation to energy efficiency, and behavioural change strategies. It presents an overview of some prominent models of technology adoption, including their extensions and limitations. This chapter concludes with a brief summary of the main points of the chapter.

2.2 Definition of a Smart Home

Terms, such as “Smart Home”, “Intelligent home” and “home networking” have been used to refer to advanced home control systems (Berlo, 2002). According to Carner (2009), “Domotics” is another term that describes Smart Home technology and derives its meaning from two Latin words *domus* and *informatics*; *Domus* means home and *informatics* means the science of data processing, categorisation, and retrieval. Although the term “Smart Home” is now commonly used to describe a home in which mechanical and digital devices communicate with one another, the term “Smart House” was first used officially by the American Association of Builders in 1984 to refer to homes equipped with interactive technologies (Harper, 2003).

The definition of a Smart Home has changed considerably over the past few decades. As far back as the 1980s, researchers from various disciplines have made several efforts to define a Smart Home. However, to date there is no commonly agreed definition.

Pragnell et al. (2000, p. 1) defined a Smart Home as the use of:

> electronic networking technology to integrate the various devices and appliances found in almost all homes, plus building environment systems more common in factories and offices, so that an entire home can be controlled centrally – or remotely – as a single machine.

Pragnell et al's definition excludes monitoring of home devices and appliances. As suggested by Ricquebourg et al. (2006), developments in Smart Home technology have introduced monitoring capabilities, in addition to its original use, to control environmental systems, such as lighting and heating.

Pragnell et al's definition was quoted by Carner (2009, p. 9) but with a twist as: "electronic networking technology to integrate devices and appliances so that the entire home can be monitored and controlled centrally as a single machine".

Carner, in quoting Pragnell et al's definition, included the word "monitored", which suggests that monitoring is a sine qua non for Smart Home technology.

Aldrich (2003, p. 17) defines a Smart Home from the socialist perspective as:

> a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond.

The Building Research Establishment (BRE) briefly defined a Smart Home as "a home where technology has been introduced with the aim of enhancing lifestyle or quality of life." (BRE, 2003, p. 3).

BRE went further to explain that home Internet access is fundamental to Smart Home technology because it unlocks the possibilities of remote monitoring and control of home systems.

King, quoted by Scott (2007), defined a Smart Home as "a dwelling incorporating a communications network that connects the key electrical appliances and services and allows them to be remotely controlled, monitored or accessed." (King, 2003, p. 2).

Although King's definition does incorporate the monitoring capability of a Smart Home, it can be argued that King's definition appears to be more technologically focused.

A Smart Home can be defined as, "a home fitted with Information and communication technology used to centralise management, control and monitoring of appliances, electronic devices and building components for better quality of living."

A Smart Home offers a wide range of new applications focused on energy conservation, care, convenience, comfort, safety and security. Smart Homes use networking technology to integrate security systems (e.g. alarms, motion detectors), environmental control systems (e.g. air conditioning, water, lighting, energy management), communication systems (Internet and telephone), home entertainment (audio & visual), and health (Laberg, 2004).

2.3 Historical Emergence of the Smart Home Concept

The dramatic influx of technology into domestic homes in the 20th century significantly influenced the housing design and construction that led to the emergence of the "Smart Home" concept. In order to understand the emergence of the Smart Home concept, it is imperative to briefly discuss the revolution in domestic technology that was created by the advent of home electricity in the early 20th century, and the introduction of information technology (IT) at the end of the 20th century.

2.3.1 Electricity Enabled Transformation of Domestic Technology

The introduction of electricity into homes in the early part of the 20th century replaced gas and glowing sources as a controllable, convenient, clean and safer form of energy. Electricity can be considered a seedbed of innovation for the development of new domestic technology at the beginning of the early 20th century (Aldrich, 2003). This brought about the introduction of home electrical appliances, such as vacuum cleaners (health and hygiene), sewing machines (homeworking and repairs) and food processors (home automation) (Gann et al., 1999), and represents the first major motivation for change in domestic technology (Aldrich, 2003).

According to Gann et al. (1999), electricity spawned the growth of major household appliance and equipment manufacturers, who promised to ease the burden of household chores and to make science fiction stories of home automation a reality. Some early examples of domestic brands include: Belling, Creda, Electrolux, Ferranti, Hoover and Kenwood. Forty (1986) as cited by Gann et al. (1999) and Aldrich (2003) explained that these domestic machines and appliances were first introduced into the home in the first quarter of the 20th century in response to growing concerns by the middle-class to a shortage of domestic servants experienced at that time. Hardyment (1988), as cited by Gann et al. (1999) and Aldrich (2003), also explained that the introduction of home electrical appliances and machines was intended to replace domestic servants and help alleviate domestic chores.

FIGURE 2.1 – Bendix washing machine advertisement (Gann et al., 1999, p. 11)

By 1970, many homes were equipped with technology, such as central heating and thermostats, as well as labour-saving domestic devices, such as kettles, toasters, cookers, coffee and tea makers and washing machines (Aldrich, 2003). Aldrich further explained that by the 90s, cordless and mobile phones for domestic use were introduced, and new home entertainment technologies, such as cable television and multimedia PC, began to surface in the domestic market.

2.3.2 ICT-Enabled Transformation of Domestic Technology

According to Barlow and Gann (1998), as cited by Aldrich (2003), since the 1980s major initiatives have been made by home appliance and equipment manufacturers to develop digital systems and components suitable for home use. Some major breakthroughs include the introduction of digital switching as a replacement for electromechanical switching, and optical fibres. The introduction of new communication networks and new end digital devices as suggested by Aldrich (2003) was the second major motivation for change in domestic technology and unlocked the possibilities for a bidirectional network link between devices, systems, and people within and outside the home. According to

Aldrich, this led to the emergence of the Smart Home concept.

The emergence of wired and wireless communication technology, such as the Internet, in the 1990s increased the scope for value-added managed services in the home (Sandström, 2009). The rapid technological progress, and the ever increasing number of domestic technological products and services, provided the possibility to envisage, publicise and achieve new connected homes. Junestrand (2004) as cited by Sandström (2009) explained that these homes offer better connectivity with the outside world via home gateways, and also extend the functionality of various appliances linked in the home through home networks. Most domestic appliances now include microprocessor "intelligence" controls, which make it possible for users to select different performance functions.

According to Gann et al. (1999), there are two forms of Smart Home which have emerged: (1) home automation, which involves the use of "intelligent" domestic appliances (traditional approach) and (2) home automation with interactive computing, communication and entertainment services within and beyond the home. By 1984, home automation had garnered interest from the fields of architecture, building, energy conservation, electronics and telecommunications and this led to the formation of a group in the US called "Smart House" by the National Association of Home Builders (NAHB). Their primary focus was to revolutionise the new home market with the inclusion of Smart Home technology (Aldrich, 2003).

2.4 Smart Home Research Initiatives

In 1978, Hitachi and Matsushita proposed the first home control system in Japan (Zhang, 2003). Two years later, Yoneji Masuda in his book "The information Society As Post-Industrial Society" talked about transformations in society, information and knowledge domain and how technology will provide opportunities for innovation and high comfort standards. Since the beginning of 1980, manufacturers, such as Matsushita, Toshiba, Mitsubishi, Sony, Sanyo and Sharp, have published blueprints for home automation systems, built demo houses and launched their own brand (Zhang, 2003).

In 1988, an "intelligent" house was built in Tokyo by a group of Japanese companies, directed by Professor Ken Sakamura, who conceived "The Real-time Operating system Nucleus" (TRON) computer architecture in 1984. The house had its ceilings, floors, walls, doors and windows fitted with more than 400 microprocessors that operate in the background to control lighting, air-conditioning, audiovisual equipment and other devices.

Networked sensors were used to monitor conditions within and outside the house, while communication systems linked to an external database were used for bidirectional transmission of images and sounds within the house through telephone, TV terminals and speakers installed in each room, which were connected to an external database. This project cost $6.9 million and received worldwide media attention (Nakagawa, 1990).

The US gas utility industry sponsored the first “Smart House” project where a research house fitted with gas pipes and appliances was built for demonstration purposes. However, the project suffered a setback due to a lack of intelligent control features, thereby failing to create the opportunity for the electric utility industry to showcase how electric-enabled technologies can revolutionise the new home market. In 1982, American Telephone & Telegraph (AT&T) pioneered the concept of “Intelligent Building” in its office tower “The Informart Building” erected in Dallas. AT&T developed its Premises Distribution Systems (PDS) cabling infrastructure product with this concept in mind. PDS evolved into the Intelligent Building System (IBS), which led to today`s Systimax Structured Cabling System (SCS).

Following the launch of the “Smart House” project by NAHB in 1985, a consortium of electric power companies came together to build the first all-electric Smart House. The objective of this was to demonstrate benefits, such as comfort, convenience, attractiveness and efficiency (Electric Power Research Institute [EPRI], 1992). In January 1991, the first “Smart House” was showcased, attracting over twenty-five thousand home builders and potential home buyers. Like the “intelligent” house project in Japan, this also garnered worldwide attention with an overwhelming response that clearly indicated the public's enthusiasm for innovation in intelligent homes (EPRI, 1992). Other Smart Home projects initiated in the 20th century include the Massachusetts Institute of Technology (MIT) Intelligent Room (Brooks, 1997), Neural Network House at the University of Colorado at Boulder (Mozer, 1998) and the Georgia Tech Aware Home (Kidd et al., 1999).

2.4.1 Academic Research

Over the past decade, a large number of Smart Home research projects have emerged from academia (KTH’s comHOME, MIT’s House of the Future and the University of Massachusetts Intelligent Home, among many others) and in the residential building sector (Cisco’s Internet Home, Microsoft’s EasyLiving, Siemens Smart Home and Intel Architecture Labs) (Bartolomeu et al., 2006; Reinisch et al., 2010).

The MavHome (Managing An Intelligent Versatile Home) project by Cook et al. (2003)

aims to maximise users' comfort and throughput and minimise energy costs. The focus was to create an environment that behaves like an intelligent agent that observes the state of the home with the aid of sensors, executing certain actions via device controllers (Das et al., 2002; Cook et al., 2003). Cook's scenario typifies MavHome operations as something authors of ten years ago would have seen as science fiction, but in today's technology, is all feasible. The scenario depicts a Smart Home that integrates technologies from databases, robotics, machine learning, mobile computing, and multimedia computing.

Reinisch et al. (2010) in their paper "ThinkHome Energy Efficiency in Future Smart Homes", proposed a system concept that utilises artificial intelligence in Smart Homes, with the aim of minimising energy consumption and optimising users' comfort. The authors argued that there are inadequate energy efficiency technologies to support household energy savings despite the growing interest in domestic energy conservation. The project utilises automation systems and artificial intelligence mechanisms to enhance the sustainability of buildings. The system is designed to dynamically adjust preferences of inhabitants through learning capabilities and context awareness in the home, offering comfortable living and energy efficiency to households, while also recognising their needs. The system architecture utilises a knowledge base that integrates a wealth of information, such as building materials, thermal properties, building layout and orientation, all of which are sourced from disciplines that include architecture, engineering and construction. The authors showed that by applying the right ontology in the implementation of the systems knowledge base, it made possible an early introduction of system intelligence (knowledge inference and reasoning) in the design. This permits data level decision making, thus enabling the higher control tasks. In addition to the all-inclusive knowledge storage is a multi-agent system that utilises all the stored knowledge to achieve additional energy efficient building operation. Reinisch et al. in evaluating the energy reductions and comfort gains, revealed the effectiveness of the knowledge base implanted in the agent system.

Jahn et al. (2010), as cited by Badica et al. (2013), developed a Smart Home system that uses Hydra as the middleware. Hydra enables communication of diverse embedded devices through a Peer-to-Peer (P2P) network. Connected devices in the home are integrated with wireless metering plugs to facilitate the monitoring and analysis of energy consumption in near real-time for each connected device. According to Jahn et al., maintaining a high level of energy consumption awareness in households is the key to household energy efficiency. The authors further explained that disaggregated data provides information on device specific energy consumption and cost that can help consumers improve their energy consumption behaviour. The authors identified challenges faced with presenting a high volume of data to end-users in a form which is useful for decision making. They argued that user-driven design and user evaluation are fundamental in the development of Smart Home applications.

Fensel et al. also cited by Badica et al. (2013), presented the SESAME-S system project (Smart Home System for Energy Efficiency) and discussed its services in their research paper, titled "SESAME-S: Semantic Smart Home System for Energy Efficiency" (Fensel et al., 2012). The authors explained that as energy costs continue to be on the rise globally, there is growing demand for energy efficiency solutions (Fensel et al., 2012). In response to these challenges, their project work centred on the design of highly customisable services modelled on a sensor, smart metering and building automation. They proposed an energy saving solution that uses semantically connected data to assist consumers in making well informed decisions, thereby enabling them to take stronger action to reduce their energy consumption. SESAME-S uses inexpensive parts; it is scalable and easily integrates with smart meters deployed by energy vendors; it offers a user-friendly customisable solution that is extensively adaptable to homes delivering more than 20 percent savings in energy bills.

2.5 Energy Feedback Technology

Early studies in the late 20th century have shown the effectiveness of technology-based feedback mechanisms on household energy consumption, however, with inconsistent impact estimates (Katzev and Johnson, 1987; Farhar and Fitzpatrick, 1989; Parker et al., 2008). IHDs (In-home Displays) are just one type of feedback mechanism, which provide energy consumption feedback to consumers. They have generally received positive responses from consumers in trials where they provide an opportunity to counterbalance customer discontent with increasing energy prices by enabling consumers to take control of their energy consumption (Accenture, 2011).

Research (including comprehensive meta-analysis of information based energy conservation experiments) has shown that IHDs that deliver real-time energy consumption feedback have the potential to reduce energy consumption by approximately 4 - 13 percent (Ehrhardt-Martinez et al., 2010; Faruqui et al., 2010). Studies that examine the persistence of the effect of technology-based feedback on energy savings showed that the effects fade over time after a brief period of significant reductions (van Dam et al., 2010; Houde et al., 2013). Other studies by researchers, such as Paetz et al. (2012), have shown positive consumer reactions to energy feedback technology, particularly in relation to financial cost savings.

2.5.1 The Effectiveness of IHDs

Van Dam et al. (2010) in a case study, presented the results of a 15 month pilot with IHDs in the Netherlands. The case study examined the mid-term (over 4 months) effectiveness of home energy management systems (HEMS), with a focus on how the development of energy-saving behaviour impacts sustainable energy savings after four months of using an IHD. The authors proposed the following 3 hypotheses:

1. Energy savings can be realised in the short term (less than 4 months).

2. Energy savings are not sustained in the medium to long term (after 4 – 15 months).

3. There is a correlation between habitual use of an IHD and sustained energy savings in the medium to long term.

The results of their study, which are consistent with findings by a host of researchers, such as Schwartz et al. (2013), Magali et al. (2013), and Vine et al. (2013), suggest that IHDs can potentially help householders reduce their energy consumption but with large variations in energy savings estimate. While the results of Van Dam et al.'s study showed initial savings of 7.8 percent, other studies showed varying results in energy savings.

In a study by Ontario Hydro on the impact of real-time feedback, Dobson and Griffin (1992), as cited by Parker et al. (2008), revealed that electricity savings of 13 percent were achieved in 25 Canadian homes and that these savings persisted even after the IHDs were removed.

According to Wood and Newborough (2003) as cited by Stein (2004) and Faruqui et al. (2010), a Canadian IHD study published in the 1980s found 4 to 5 percent energy savings, in Norway, direct feedback on energy consumption reduced customers' energy use by about 9 percent, while in the UK, a study using IHDs for cooking in 44 households showed an average reduction in energy consumption of 15 percent.

In Japan, Ueno et al. (2005), as cited by Parker et al. (2008), in a study that evaluated the impact of real-time electric feedback showed a 12 percent average energy reduction in 10 homes.

In Massachusetts, US, a study by PA (Personnel Administration) Consulting Group, which involved conducting an impact evaluation of the Residential Smart Energy Monitoring Pilot programme (designed and implemented by Cape Light Compact) on 100 households, showed a 9.3 percent average daily reduction in energy consumption (PA, 2010).

Smart meter trials carried out in Ireland between 2009 and 2010 by the Commission for Energy Regulation (CER) on a large number of Irish households to which various levels of feedback and time-of-use tariffs were applied, showed that households with IHDs had the largest reductions of 3.2 and 11.3 percent in peak and overall demand respectively (across all tariff rates) (Carroll et al., 2013).

A comparison of these pilot studies cannot be undertaken due to their heterogeneity in relevance to demographics, design, sample size, pilot duration, and location. LaMarche et al. (2012), noted the bias in studies that evaluate the effectiveness of feedback, and explained that volunteers in some studies might be more motivated than the average homeowner. However, the energy saving trends illustrated by the studies suggest that IHDs enhance energy conservation.

There is a gap in understanding the ideal combination of the type and frequency of information displayed to achieve the utmost energy savings (Allen and Janda, 2006; Parker et al., 2006; Roth and Brodrick, 2008). Allen and Janda (2006) as cited by Roth and Brodrick (2008) suggested that it is uncertain if real-time feedback engenders significant savings than less frequent, i.e. weekly or monthly feedback. According to Darby (2006), as cited by Roth and Brodrick (2008), some studies have shown that energy savings in the increment of 5 percent can be achieved with real-time feedback. Roth and Brodrick pointed out that it is uncertain if more energy savings are realised with more sophisticated displays than more basic displays. An important point made by Darby, as cited by Roth and Brodrick, is that an IHD that displays real-time energy consumption can provide fairly similar feedback, because it reveals how household behaviour affects energy consumption (Darby, 2006; Roth and Brodrick, 2008).

Van Dam et al.'s second hypothesis, i.e. the persistence of energy savings, was falsified by results obtained in their study, which were consistent with the findings of Houde et al. (2013) in which a feedback mechanism that consisted of an electricity consumption monitoring device, a web-based monitoring application, energy cost and usage comparison was installed in over 1500 households. According to Hounde et al., it is obvious that households are able to reduce energy consumption by responding to feedback; however the challenge is to prevent these reductions from fading with time. As suggested by Hounde et al., future research should focus on developing research designs that detect change, as well as effective feedback interventions and strategies, for sustainable energy efficiency.

On the contrary, evidence from an extensive review of 27 household studies of the persistence of feedback-induced energy saving by Ehrhardt-Martinez et al. (2010) does suggest that energy savings are sustainable with an increase over time in some cases. Despite the evidence from the meta analysis of Ehrhardt-Martinez et al., the authors underscore the need for more research on the sustainability of energy savings over a two year period or longer. According to Darby (2006), sustainability of savings will occur when feedback promotes inherent energy saving behaviour i.e. when households develop new habits. Darby further explained that continuous feedback is necessary for behavioural change to be maintained and to stimulate new changes in behaviour. To date, there is no evidence from studies to show that long-term feedback studies provide higher savings than short-term studies. It may be practical however to assume that long-term feedback projects enhance habitual changes and can therefore lead to sustainable savings during and after feedback studies (Fischer, 2008).

Results from Van Dam et al.'s study were inconclusive on their third hypothesis that states that there is a correlation between habitual use of an IHD and sustained energy savings in the medium to long term. However, research carried out in Ireland by Carroll et al. (2013), in an attempt to gain insight into energy demand reductions by exploring the role of improved knowledge through enhanced feedback, revealed that feedback significantly increases a household's appliance knowledge, particularly for households with IHDs; akin to findings by Schwartz et al. (2013). However, the authors found no correlation between knowledge improvements and demand reductions. Despite the difference in terminology i.e. "knowledge improvement", "habitual use", "frequency of interaction", used in the studies by Van Dam et al. (2010), Carroll et al. (2013) and Schwartz et al. (2013), it can be argued that a comparison of their findings in relation to the third hypothesis of Van Dam et al., could be based on the premise that all three terminologies refer to energy literacy. Although Van Dam et al.'s results were inconclusive on the third hypothesis and Carroll et al, found no correlation between knowledge improvements and demand reductions, Schwartz et al.'s study revealed that knowledge acquired by using IHDs changed energy consumption patterns.

Faruqui et al. (2010) put forward an argument questioning the usefulness of feedback information from IHDs to consumers and the possibility that they may serve as energy saving reminders. The authors argued that if real-time, quantitative and qualitative information provided by IHDs enhanced household appliance knowledge improvement, then a change in consumer behaviour is likely to be preserved. They further argued that If IHDs act as a physical reminder to save energy, then households would eventually adapt to the presence of IHDs, resulting in their ultimate drift to the background (Faruqui et al., 2010). However, Carroll et al. explained that it is likely that feedback information from IHDs serve as a reminder and motivator rather than a knowledge improvement tool (Carroll et al., 2013). Given the limitations (possibility of bias) of self-reported data as explained by Carroll et al., accurate research on the correlation between knowledge improvements and energy reductions still needs to be carried out. As suggested by Carroll et al., testing the actual knowledge of participants in future trials could help eliminate bias associated with self-reported knowledge. It can therefore be argued that the inconclusive results of Van Dam et al.'s third hypothesis could also be due to the self-reported data used in evaluating the frequency of interaction of participants with feedback from IHDs.

2.6 IHD Products and Trends

There has been an increase in the number of new home energy management products and companies over the past decade, ranging from basic IHDs to whole home control systems. Table 2.1 shows some IHD companies and their products.

TABLE 2.1 – IHD Companies and Products (Adapted from LaMarche et al. 2011)

Company	Product(s)	Cost
2 Save Energy	The Owl micro	$77.25
	The Owl	$139.95
AlertMe	Energy Monitoring Start Kit	starting at £50
Black and Decker	Home Power Monitor	$99.99 ($24.99 Amazon)
BlueLine Innovations	PowerCost Monitor	$109.00 ($72.00 Amazon)
Brultech	ECM-1240	$170-600
CurrentCost Ltd	ENVI	$129.00
	EnviR	£30-50 (UK)
DIY Kyoto	Wattson display + Holmes software	£100 (UK)
Eco-eye	Elite 200	£90 (UK)
	Eco-Eye Mini	£90 (UK)
Efergy	Elite	$123.76 ($109.87 Amazon)
	E2	$138.05
eGauge	eGauge Kit	$752
Energy Inc.	TED 1000 Series	$164.95
	TED 5000 Series	$239.95
WattVision	SaveOmeter	£80
	WattVision	$250

IHD products differ in their range of features and specifications (Accenture, 2011), offering features, such as information on utility rates and charges, and controlling appliances remotely (National Disability Authority [NDA], 2013). As shown in figure 2.2, Accenture (2011) classified IHDs into product categories based on the following three characteristics:

1. Type of Feedback (from basic Pricing alerts to robust analytical data).
2. Communications Technology (Communication interface between the user and the device).
3. Backhaul Technology (Communication between the device and the meter).

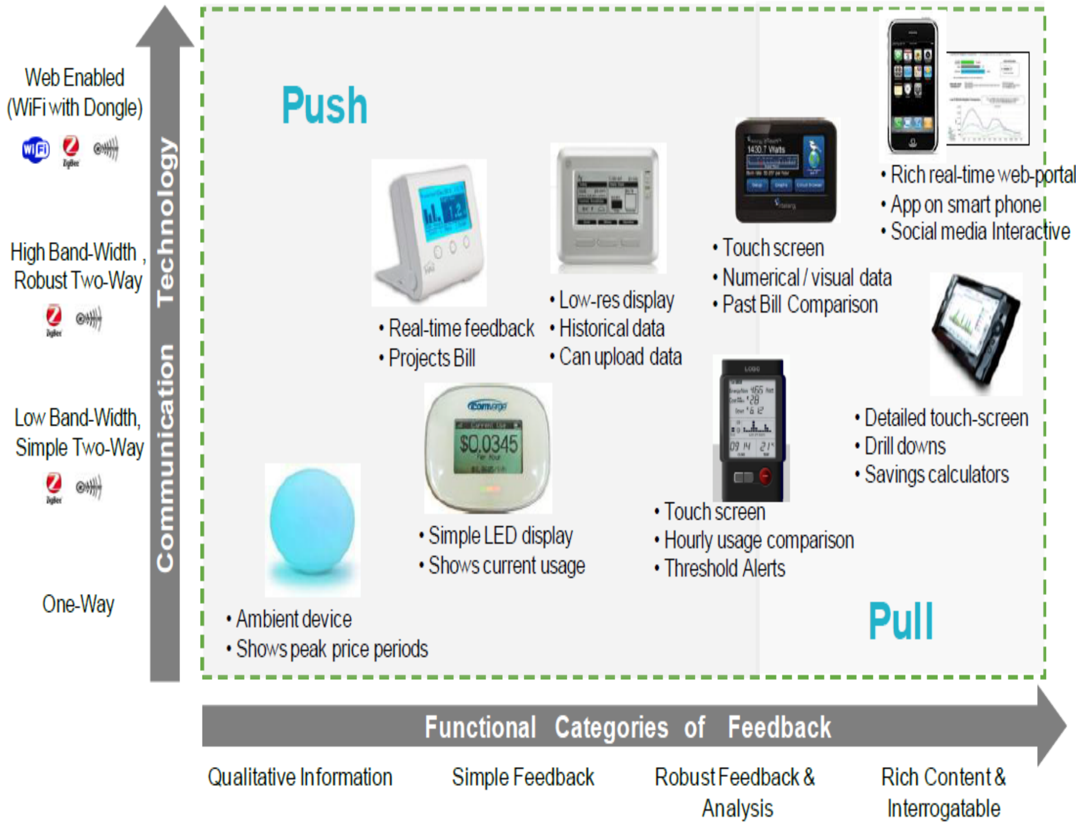

FIGURE 2.2 – Range of IHD Functionalities (Accenture, 2011, p. 14)

A large number of IHDs monitor whole household electricity consumption in real-time, displaying information, such as current energy usage in kW, cost per hour, or daily usage in kwh, but are not diverse in the types of information and visualisation presented to households (LaMarche et al., 2011). At a basic level, IHD reports only show real-time whole house energy consumption. More sophisticated IHDs display more specific information, such as changing electricity rates or demand response events, appliance specific energy consumption, past energy consumption data, and projections of monthly energy consumption and costs (EERE, 2011). Accenture pointed out that "the types of feedback (or functional categories) constitute the main difference that the end-user will experience in using IHDs" (Accenture, 2011, p. 15).

According to Ehrhardt-Martinez et al. (2010), as cited by LaMarche et al. (2011), some IHD products include web software packages that provide additional information, such as household baseline energy consumption, energy consumption trends, projections, alarms, social comparison, and goal tracking. Some IHDs are based on open standards allowing connection from smartphone applications or web applications that have dashboards (LaMarche et al., 2011). According to LaMarche et al. (2012), supplementing IHDs with web portals that exhibit a high degree of usability, has the potential to increase their uptake. A survey conducted by LaMarche et al. (2012) to determine the preferred IHD presentation medium of households showed that early adopters prefer, and will probably embrace, smartphone applications over web dashboards or IHDs.

Makonin et al. (2013) proposed an all-inclusive open source hardware and software solution called Arduino Power Meter Reader (APMR). APMR monitors energy consumption and stores historical energy readings, thereby keeping households well informed of their energy use in real-time via an IHD. The authors emphasised the importance of providing consumers with appliance level data, which in their future work will include the introduction of a load disaggregation algorithm. The algorithm will provide appliance specific information, such as appliance status and energy consumption. They explained that appliance specific data will empower consumers to make well informed decisions on energy reduction when participating in demand-response (DR) programmes. The APMR prototype system was built using open source hardware and software that include Adruino (power monitoring), Linux and MySQL (database server), and Electric Imp (in-home display). According to the authors, their prototype allows for further customisation to suit the needs of consumers. By leveraging on open source technologies, IHD or Smart Home manufacturers can reduce unnecessary cost, which was identified by Lin (2013) as one of the key issues of building a Smart Home.

2.7 Energy Efficiency Initiatives Involving IHDs

Global pilots and trials conducted by utility providers and governments have shown that energy consumption information provided by IHDs can potentially help consumers adjust their energy use behaviour in order to save energy and reduce their bills (Accenture, 2011). According to the International Energy Agency (IEA), the strategic position of utility providers in energy markets will be crucial over the coming decades in delivering energy efficiency and minimising greenhouse gas emissions (IEA, 2013). Utility providers act as a middleman between consumers and utility companies and can therefore stimulate energy saving activities in diffuse markets.

In Europe and Australia, there is a rapid increase in the number of IHDs deployed; mainly driven by smart meter mandates and the customer retention motivations of utility providers (Delta Energy & Environment [Delta-ee], 2011). In some cases, households will be provided with IHDs as part of a government and/or utility provider efficiency program (Office of Energy Efficiency and Renewable Energy [EERE], 2011).

Many utility providers see business retention or new business opportunities as the driver for engaging with customers in energy saving programmes and initiatives; a view similarly shared by the European Environment Agency (EEA, 2013), while other utility providers are required by regulation to engage with customers to develop energy efficiency programmes and initiatives (IEA, 2013). Some European utility providers are offering customers IHDs with limited functionality to stay ahead of competition, and to maintain customer retention (Delta-ee, 2011).

In the UK, four energy suppliers carried out trials on over 60,000 households to evaluate the impact of various interventions (individually or in combination) on household energy consumption. The Energy Demand Research Project (EDRP) as it was called, was a major project conducted between 2007 and 2010. The interventions were mainly aimed at minimising household energy consumption, while others focused on shifting energy consumption away from periods of peak demand. Smart meters and IHDs were installed to provide real-time feedback on energy consumption. Results from the trials showed that IHDs were crucial in reducing household electricity consumption while gas savings could be achieved with only a smart meter, although the persistence of gas savings was lower than that of electricity savings with IHDs. An average of 3 percent savings was achieved with a combination of smart meters and IHDs though differences depended on the type of fuel, demographics and time of use (Office of Gas and Electricity Markets [Ofgem], 2011). According to Ofgem, IHDs appear to be more valuable to households in confirming savings after efforts have been made to reduce consumption, than when being used to initiate savings.

The European Commission has proposed several measures to increase energy efficiency. One such measure includes the introduction of smart meters to allow consumers to optimise their energy use. The Irish Smart Meter Electricity Customer Behaviour Trial, established by the Commission for Energy Regulation (CER) ran from 1st January 2009 to 31st December 2010. The project involved the roll-out of IHDs developed by ESB Networks and Elster to over 1,200 ESB customers. The IHD provided real-time feedback on electricity consumption and cost to the customer. The electricity trials resulted in 2.6% savings in the first six months and 2.8% savings in the last six months when customers were provided energy usage statements only. When provided with IHDs, in addition to energy usage statements, customers saved 4.0% in the first six months and 2.4% in the last six months. As pointed out by Opower (2013), these results suggest that IHDs do not deliver long-term energy savings, consistent with findings by Van Dam et al. (2010). The resultant benefits achieved from changes in electricity use behaviour coupled with the low operational costs as demonstrated in the trial led to the final decision by the CER to approve the roll-out of smart meters for both electricity and gas to all Irish households between 2014 and 2019. Utility providers will be required to offer IHDs to all customers, which will be capable of displaying usage data about gas in addition to electricity (CER, 2012).

In 2010 US electric utility company CenterPoint Energy and the Department of Energy conducted a pilot programme with 500 residential electricity customers in the Houston area, using a simple battery-powered wireless portable IHD, which gets energy-use data from a smart meter, displays real-time energy consumption in addition to a projection of the monthly bill, and time of use pricing (CenterPoint Energy, 2011). The programme, which can be argued to be regulatory driven, provided participants with the option to view near real-time information updated on a website every 15 minutes, in addition to monthly and yearly data.

FIGURE 2.3 – CenterPoint in-home display (CenterPoint Energy, 2011, p.2)

The survey results of the pilot programme showed that 71% of customers indicated that feedback from the IHD helped in changing their energy use behaviour and this resulted in a reduction in energy consumption. According to CenterPoint Energy, the pilot showed that providing real-time information can prompt a behaviour change in consumers (CenterPoint Energy, 2011), consistent with evidence from past studies, which suggest that changes in energy use behaviour can result in energy savings (Ehrhardt-Martinez et al., 2010; Accenture, 2011).

Irish energy supply company Airtricity launched an integrated marketing campaign in 2011 encouraging Irish households to change their energy-use behaviour in order to significantly reduce domestic energy bills (Airtricity, 2011). Their campaign message was that Irish households can save up to €100 per annum by reducing their annual energy consumption by 10 percent with Airtricity's energy saving tips, such as the installation of an IHD.

According to Stephen Wheeler, Airtricity's Managing Director,

> Managing household bills is a struggle for a lot of people at the moment but many consumers do not understand that small actions like switching appliances off at the wall and turning off lights can make a huge difference to their energy consumption and costs. By cutting our annual home energy use by up to 10% each household can save up to €100 per annum. At Airtricity we want to help customers realise these savings and our new Airtricity Home Energy Monitor will provide customers with the real-time energy-use information that will encourage changes in behaviour to significantly reduce annual energy costs (Airtricity, 2011).

FIGURE 2.4 – Airtricity in-home display (Airtricity, 2011)

A free Airtricity IHD (Figure 2.4) was offered to all new customers who switched online to Airtricity's cheapest online tariff under a two-year contract, which can be argued to be driven by business retention and business development, as identified by IEA (2013) in their analysis of some energy efficiency initiatives. Some information displayed by the IHD includes:

- The current electricity consumption, as well as its cost per day and per month.
- Energy consumption and cost of an appliance (by simply turning it on).
- A graphical representation of how much electricity was used the previous night, day and evening.
- Total energy consumption over the last day, last week and last 30 days.

Consumers have the option to set a baseline usage by turning off appliances that are not required to remain constantly plugged in. Consumers with night saver meters have the option to set a night rate in addition to the standard rate. Unlike most energy efficiency programmes or initiatives, no results were published for this trial.

In 2011, Knowatt a household energy use feedback scheme developed by the Portuguese energy group Energias de Portugal (EDP) was selected for funding by the Portuguese regulator ERSC (Energetic Services Regulatory Entity) in a smart metering project. IHDs were installed in 100,000 households to help monitor daily energy consumption and the energy feedback information was analysed and used to make recommendations to households on how best to optimise energy consumption by changing their energy use behaviour IEA (2013). According to IEA, regulatory and market opportunity are the drivers for the Knowatt scheme. Although the energy saving results are yet to be published, it is estimated that the programme will realise energy savings of 107 KWh annually per household with an annual estimate of 1.1 GWh for the whole programme (IEA, 2013).

The UK Department for Energy and Climate Change (DECC) also announced their intention to roll-out smart meters to many homes in the UK by 2020. All domestic customers will be offered an IHD capable of displaying near real-time energy consumption information and cost. The display will also show information about energy consumption in the past day, week, month and year (DECC, 2013) .

In Australia, the VEET (Victorian Energy Efficiency Target) scheme is a regulatory driven initiative of the Victorian state government and promoted as the Energy Saver incentive (ESI). The Victorian state government required that smart electricity meters be installed for 2.5 million residential and small business customers by the end of 2013. IHDs were not included at the beginning of the ESI scheme to complement smart meters. However, IHDs were later made available to Victorian residents in July 2013 following recommendations by Accenture (2011).

On the 6th of May 2014, in Cambridge, UK, Green Energy Options (geo) announced the results of IHD trial demonstrating water, energy and cost savings. The Anglian Water trial, which lasted for a year, involved 422 customers from different socio-economic backgrounds and used geo’s Ensemble Water; a colour in-home smart water display shown in Figure 2.5.

FIGURE 2.5 – geo Ensemble Water in-home display (geo, 2014)

Results from the trial showed an average decrease in water consumption of 3 - 4%, with the highest reductions at 8%. This implies a saving potential of 30% on domestic energy generally used to heat water (geo, 2014). According to Paul Glass, Metering Change Manager at Anglian Water Services,

> Not only can the IHD help customers to reduce their water bill, but their energy costs as well if they use less hot water. The environment benefits too, with less extraction, and less energy used for treatment, pumping and water recycling (geo, 2014).

2.8 The Water-Energy Nexus at the Household Level

Energy has an intricate connection to water supply and use (Consumption Environment Sustainability, 2012b). Water utility companies use energy for abstracting, supplying water, and treating both water and waste water. Households use energy when water is used through heating or cooling. The consumption environment sustainability (Consensus), in response to the position paper on the reform of the water sector in Ireland, emphasised the importance of research aimed at addressing inefficient domestic water-use practices through more direct interventions (Consensus 2012b). The Environmental Protection Agency as cited by Consensus (2012a) in the ConsEnSus Lifestyle Survey attributed 60 percent of total water demand in Ireland to household use. According to Eurostat (2012), as shown in Figure 2.6, the per capita water use in Ireland is approximately 141 litres.

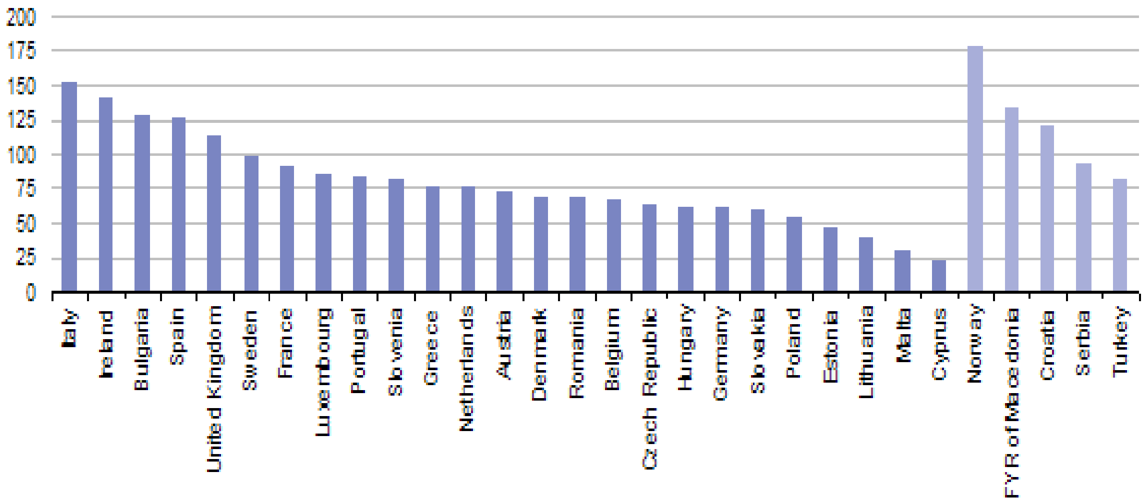

FIGURE 2.6 – Freshwater resources per inhabitant (Eurostat, 2012)

An independent survey conducted on behalf of Irish water reveals that 81 percent of households in Ireland are oblivious to how much water they actually use on a daily basis (Irish Water, 2013). Results from the survey revealed that showers use the most water in Irish homes consistent with findings (Figures 2.6 and 2.7) from surveys conducted by Energy Saving Trust (2013) and Dufferin Research (2013) in the UK and Canada respectively.

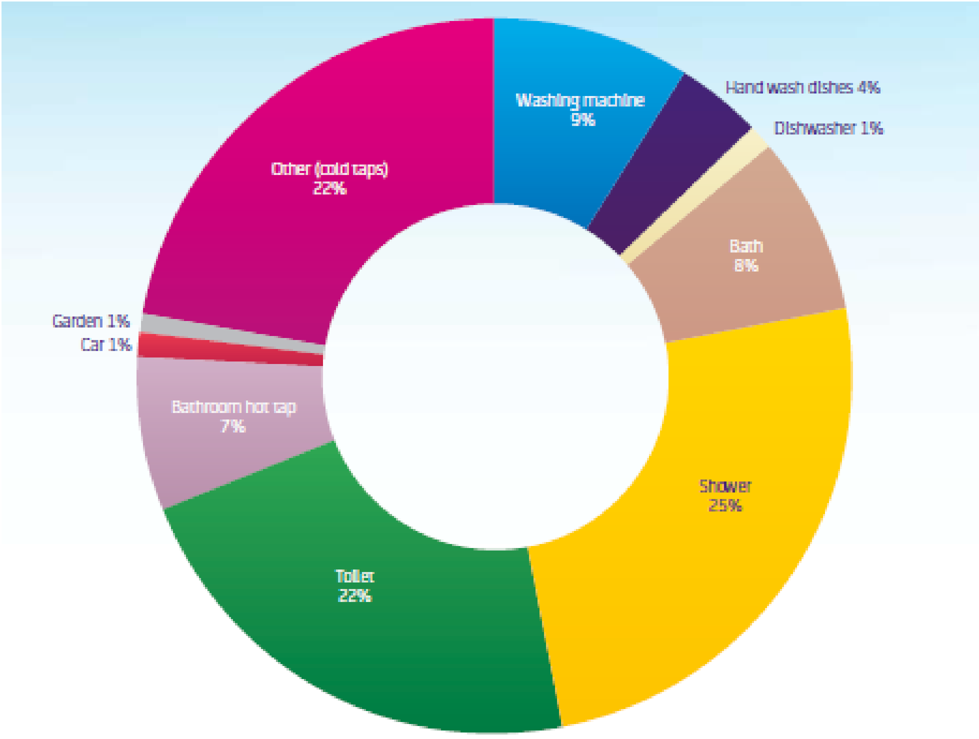

FIGURE 2.7 – Water consumption by use in UK (Energy Saving Trust, 2013, p.13)

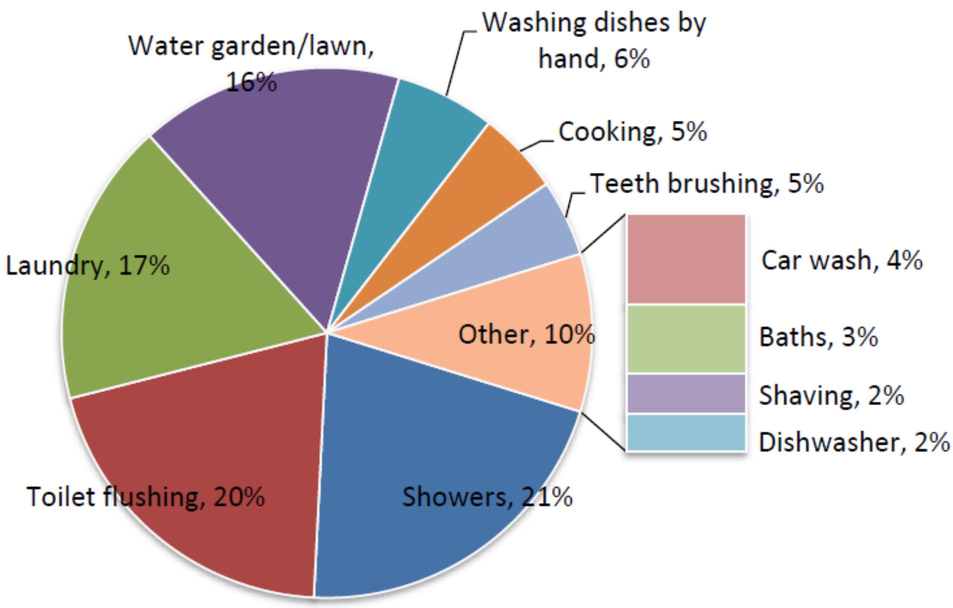

FIGURE 2.8 – Water consumption by use in Canada (Dufferin Research, 2013, p.3)

Research carried out in the UK by Energy Saving Trust (EST) and WaterWise, as cited by Consensus (2012b), showed that a large number of consumers are unaware that their energy bills can be attributed to heating and using hot water (EST and WaterWise, 2011). According to EST and WaterWise, the daily per capita water use in the UK is around 150 litres with a significant amount wasted. Water use accounts for 6 percent of all carbon dioxide emissions in the UK, with 89 percent of this coming from domestic water use (EST, 2013). EST and WaterWise explained that on average domestic water use accounts for around a quarter of household carbon emissions. If used carelessly, heating water can be one of the biggest contributors to energy bills, and with energy rates always on the rise, people will become more concerned about their water use behaviour.

Consensus (2012a) argued that the rising cost of household water treatment, as well as the planned re-introduction of water charges for Irish households, has made water efficiency an important issue, not only for policy makers and businesses, but also for consumers. When these water charges are introduced, people will have an important incentive to find ways of reducing their water use or the amount of water wasted on a daily basis.

Davies and Doyle, of Consensus, stressed the importance of complementing smart water meters with strategies that empower households to take control of their water usage and minimise costs (Consensus, 2012b). The authors advocate multi-measure water efficiency strategies that will encourage and maintain household water efficient behaviours. Davies and Doyle argued that applying a uniform volumetric water charge, independent of the use, may not result in a similar change in water-use behaviour. Results from studies of Canadian household water usage conducted by Dufferin Research (2013) support Davies and Doyle’s argument. The results showed that there is a relationship between income levels and water use; high-income households tend to use more water.

Research by the California Energy Commission (CES) as cited by Consensus (2012b) revealed that significant energy savings can be realised from water conservation, which according to Consensus (2012b) illustrates the importance of integrated water and energy monitoring, reporting, management and efficiency programmes. Davies and Doyle, of consensus, explained that integrated water-energy management and efficiency programmes will necessitate strong awareness-raising strategies.

2.9 Behaviour Change and Energy Use

Mounting evidence in academic literature proves that energy efficiency measures that target consumer behaviour have the potential for energy-use reductions (Laitner et al., 2009; EEA, 2013). According to EEA, policy makers appear to pay more attention to the feedback device than consumer behaviour and energy consumption changes. EEA explained that there is a direct correlation between the energy efficiency behaviour of households and their energy bills. More residential energy efficiency trials have been conducted than non-residential energy efficiency trials, which according to EEA, may be due to the higher potential for energy savings in the home, where it is easier to directly control energy use through behaviour changes (EEA, 2013).

There is a considerable body of knowledge and experience related to behaviour change that is deeply entrenched in the social sciences, with a move to utility providers and energy efficiency focused organisations now happening (BPA, 2011). Recent research in the social science disciplines showed gaps in previous work on energy efficiency in relation to consumer behaviour (EEA, 2013).

Shove (2003), as cited by EEA (2013), argues that evidence suggests that routine consumption practices are largely influenced by social norms, and deeply moulded by cultural and economic factors. Shove further argues that the focus should be on social norms, as they are of crucial importance in establishing consumption patterns, with various outcomes for resource usage and the environment. Robert Cialdini, as cited by EERE (2011), similarly argued that,

> decision-makers can focus too much on economic and regulatory factors when seeking to motivate others towards environmental goals. They would be well advised to consider, as well, what is known about social psychological motivators such as social norms. (Cialdini and OPOWER, 2010).

Schwartz et al. (2013) explained that the initial design ideas of persuasive feedback have not acknowledged the drivers of individual motivation and the fact that behavioural change occurs as a progression through a series of stages. He et al. (2010), as cited by Schwartz et al., explained that technology needs to meet the motivational goals at each stage of behavioural change.

According to Ehrhardt-Martinez et al. (2009), from the technology centred viewpoint, behaviour change strategies can be seen as an add-on type of programme, while in contrast, a human dimensions approach acknowledge the critical importance of behaviour in achieving energy efficiency. Laitner et al. (2009) in their paper titled “Examining the scale of the Behaviour Energy Efficiency Continuum”, emphasised the effect of changed habits, lifestyles and technology related behaviours on residential energy savings in the US. Results from their study suggest that household energy savings of about 22 percent can be achieved in the US through changed behaviours.

Behaviour change strategies are implemented using non-economic incentives to motivate households to change their energy use behaviour in order to achieve energy efficiency (EERE, 2011). Energy feedback products, such as IHDs, have been deployed in behaviour-based energy efficiency programmes to provide customers with more detailed, prompt, contextual and convenient feedback on their energy use in order to help them better manage their energy consumption and reduce their energy bills. Abrahamse et al. (2005), as cited by EERE (2011), states that behaviour-based strategies can be divided into antecedent strategies and consequence strategies. Antecedent strategies precede an energy consumption decision (e.g., energy saving commitments, goal setting, information and modelling), while consequence strategies happen after consumption occurs (e.g., feedback and rewards) (EERE, 2011).

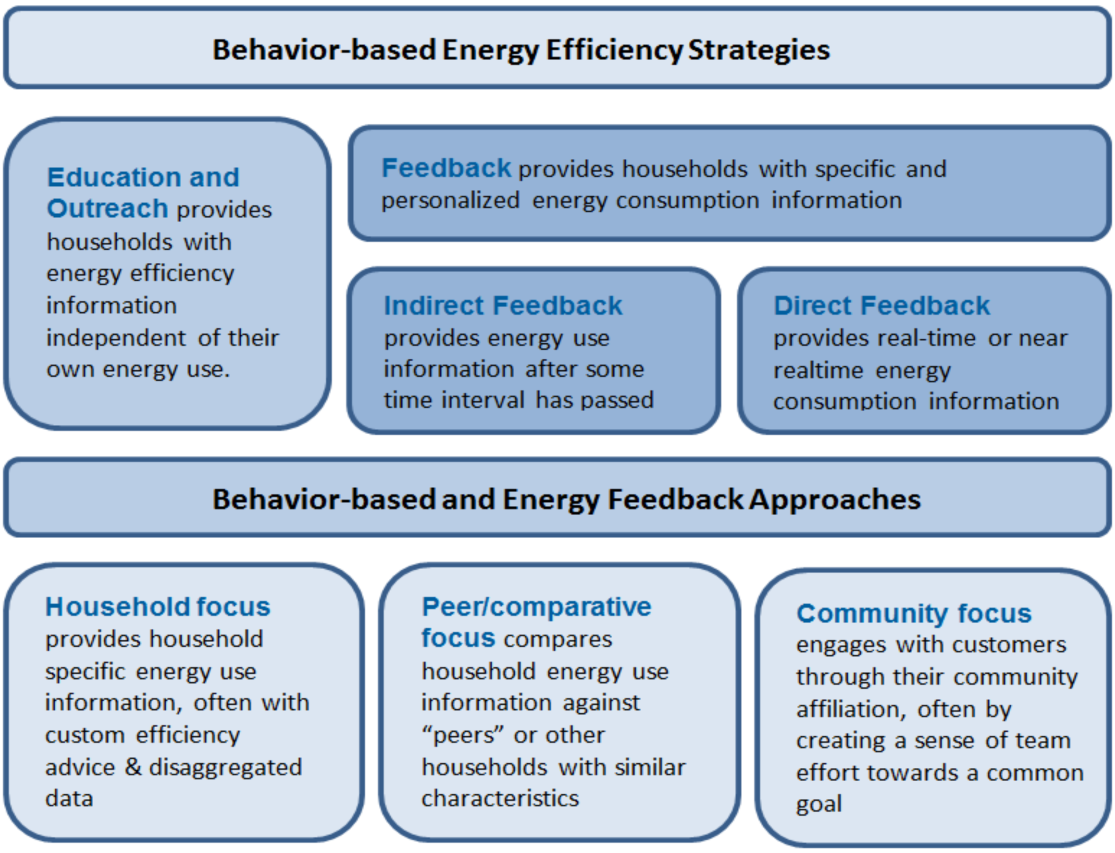

FIGURE 2.9 – Behaviour-based energy efficiency strategies & approaches (Adapted from EERE 2011)

Behaviour change strategies have the potential to explain, understand and address two crucial gaps in optimising energy efficiency and reducing energy use (Ehrhardt-Martinez et al., 2009). According to Ehrhardt-Martinez et al. (2009), energy efficiency programmes that target behaviour change can provide solutions for bridging the energy efficiency gap and the attitude-behaviour gap. Behaviour change strategies for energy efficiency programmes are based on the fact that social and psychological behaviour impact people's energy selections to a great extent akin to or more than the impact of economic factors (e.g., prices, costs and income).

Energy savings of 25 - 30 percent in the residential sector can be achieved through behaviour change strategies that incorporate programmes and policies that identify and tackle social and behavioural issues (Ehrhardt-Martinez et al., 2009). Results from a survey conducted by Ehrhardt-Martinez et al. (2009) indicate that there is a growing interest among energy experts in implementing behaviour change strategies to minimise energy consumption. Internal discussions among the professional staff at the American Council for an Energy-Efficient Economy further indicate the potential of behavioural change to achieve energy savings (Laitner et al., 2009).

According to Wood and Newborough (2003), few studies have focused on how best to influence household energy consumption behaviour. Gillingham et al. (2009) pointed out that the majority of the economic studies of energy efficiency use cost-saving behaviour by households as the basis for their analysis, while a few studies have focused on the decision making behaviour and also identify behavioural failures that impact upon cost savings. Laitner et al. (2009), explained that in order to completely understand what motivates human behaviours, it is vital that people should be understood as more than economically rational actors. According to Laitner et al., due to the complexities of human nature, there are several dimensions that are equal or even more crucial in establishing how best to promote an optimal level of energy efficiency. Research has shown that by combining household characteristics, such as convenience and perceived social status with the latest technologies, consumer uptake of energy efficiency measures can receive further boost (Ehrhardt-Martinez et al., 2008; Ehrhardt-Martinez, 2008a; Ehrhardt-Martinez, 2008b; Ehrhardt-Martinez and Laitner, 2009).

2.10 Theoretical Models of Technology Adoption

Many theoretical models have been put forward to describe and predict users' acceptance of technology and usage behaviour with varying sets of acceptance determinants (Venkatesh et al., 2003). It is therefore pertinent that researchers who seek to identify acceptance determinants of a technology understand some of the prominent models of technology adoption.

2.10.1 Theory of Reasoned Action and Theory of Planned Behaviour

The Theory of Reasoned Action (TRA) is a theoretical model developed by Ajzen and Fishbein in 1967 while attempting to explore ways to predict and understand behaviour and attitudes. This framework focuses on behavioural intentions rather than attitudes as the principal predictors of behaviours. Studies by Ajzen (Ajzen, 1985, 1991, 2005) and other researchers revealed the inadequacy and limitations of TRA (Godin and Kok, 1996). In a review of the application of TRA to health-related behaviours, Godin explained that TRA was particularly useful when explaining behaviour that appeared to be voluntary but performed poorly with involuntary behaviours. This resulted in the inclusion of the concept of perceived behavioural control, which subsequently led to a newer theoretical model by Ajzen called the Theory of Planned Behaviour (TPB).

TPB (Figure 2.10) posits that behavioural intent is the most significant determining factor of a person's behaviour. A person’s behavioural intention is a combination of attitude toward performing the behaviour and subjective norm. Although TPB provides a framework for studying attitudes toward behaviours, factors such as personality and demographic variables are not taken into consideration. Furthermore, TPB applies to behaviour that is not under volitional control.

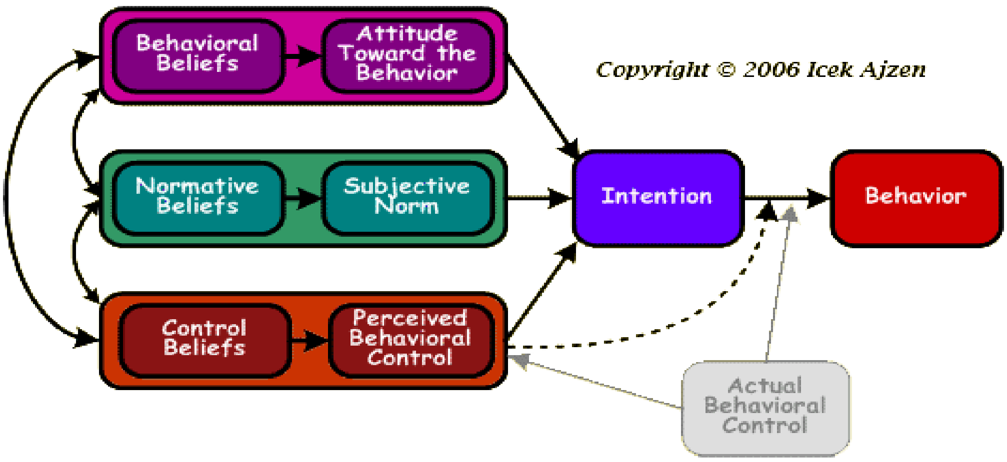

FIGURE 2.10 – The Theory of Planned Behaviour (Ajzen, 2006)

2.10.2 Technology Acceptance Model

Technology Acceptance Model (TAM) was originally proposed by Davis (1989) and is one of several theoretical models that has been used to determine how users accept a technology and how they use that technology (LULE et al., 2012). TAM shown in Figure 2.11 is a modification of TRA, customised to fit the information systems context. TAM was originally applied to technology adoption in an organisational context, with a particular emphasis on computer technology. It provides a framework for understanding how external variables influence belief, attitude, and intention to use. TAM posits that two external factors, namely, Perceived usefulness (PU) and Perceived Ease of Use (PEOU) impact a user's decision to adopt and use technology. Perceived Usefulness (PU) is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). Perceived ease-of-use as defined by Davis is "the degree to which a person believes that using a particular system would be free from effort" (Davis, 1989, p. 320) .

Evidence from many studies converge to support TAM as a model for predicting technology usage behaviour. Unfortunately, TAM does not provide an insight into the reasons behind the PU and PEOU. Furthermore, the focal point of most research in TAM has been on voluntary environments, with little consideration for mandatory settings (Chuttur, 2009). Two major extensions were proposed to address issues with TAM. They are: TAM2 by Venkatesh and Davis (2000), and Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003).

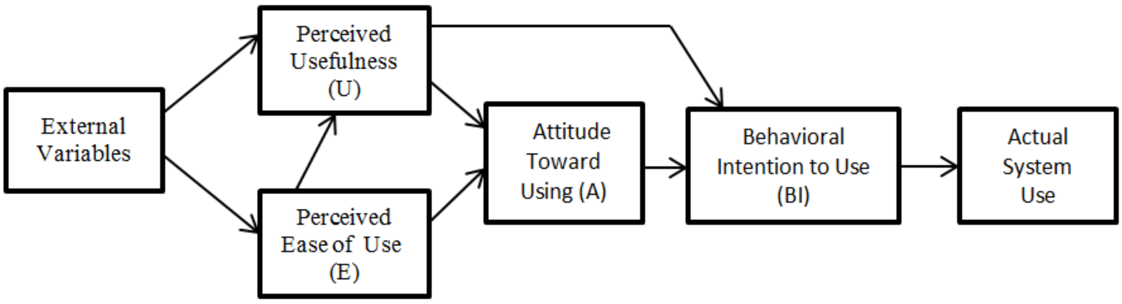

FIGURE 2.11 – Technology Acceptance Model (Adapted from Davis et al. 1989)

2.10.3 Unified Theory of Acceptance and Use of Technology

UTAUT model was formulated from eight models and integrates elements across all eight models (Venkatesh et al., 2003). It is a useful tool for measuring the probability of success for the introduction of new technology, primarily in an organisational context. In a study of the acceptance and use of technology in a consumer setting, Venkatesh et al. (2012) proposed an extension of UTAUT called UTAUT2 (Figure 2.12). UTAUT2 consist of four main constructs from UTAUT that influence behavioural intention to use a technology and use behaviour namely: performance expectancy, effort expectancy, social influence and facilitating conditions.

Venkatesh et al. (2012) introduced three new constructs in the UTAUT model: hedonic motivation (intrinsic motivation), price value, and habit. Experience, and demographic variables: age and gender, were hypothesised to diminish the effects of the constructs on behavioural intention and technology use (Venkatesh et al., 2012). As explained by Venkatesh et al., price value has a positive impact on behavioural intention to use technology, when the benefits of using a technology exceed the financial cost. It is an important differentiator between consumer and organisational use context; that is to say, in contrast to employees, the costs associated with technology use are borne by consumers.

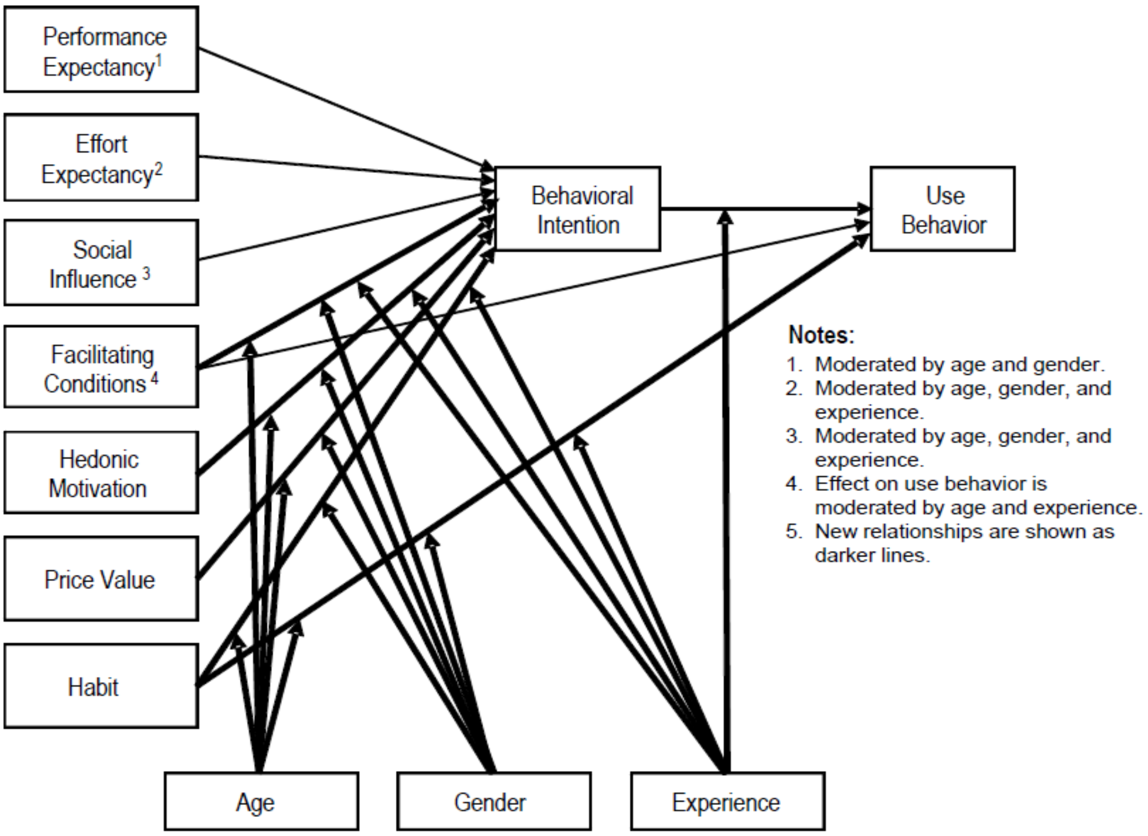

FIGURE 2.12 – Extension of Unified Theory of Acceptance and Use of Technology (UTAUT2) (Venkatesh et al., 2012, p.160)

2.11 Summary

To summarise, the rapid advancement in technology in combination with its availability and affordability has the potential to transform Smart Home from novelty to necessity. Most studies of energy feedback mechanisms have shown that by leveraging real-time data feedback provided by IHDs, households can unearth the source of energy waste and estimate the impact of actions taken to reduce waste.

Studies have revealed that significant energy savings can be realised from water conservation. The synergy created when water and energy efficiency strategies are integrated can further empower households to take control of their water and energy use, and reduce costs.

Evidence from a large body of research suggests that behaviour-based energy efficiency measures have the potential of reducing residential energy use. Studies have shown that, by combining household characteristics, such as convenience and perceived social status with latest technologies, consumer uptake of energy efficiency measures can receive a further boost.

Most models of technology adoption and use focus on organisational rather than consumer context. UTAUT2 presents novel opportunities for studying the acceptance of consumer technologies, such as IHDs. After having reviewed some prominent technology adoption models in this chapter, an adaptation of UTAUT2 described in the next chapter will be used to address the research question and to test the hypotheses presented in chapter 3.

3 Research Methodology

3.1 Introduction

This chapter summarises the research methodologies considered for this research, and in particular, explains the rationale for the research strategy selected for this study. It also describes how the research strategy was implemented using data collection methods. It presents an overview of ethical considerations. The chapter finally describes the proposed research model for this study and presents the hypotheses to be tested as part of this research.

3.2 Research Philosophies

Saunders et al describe research philosophy as "the development of knowledge and the nature of that knowledge." (Saunders et al., 2009, p. 107). According to Saunders et al., the way researchers view the world, in addition to practical considerations, will influence the approach they adopt in knowledge development. There are several different branches of research philosophy, such as positivism, realism, interpretivism, and pragmatism. The positivist, interpretivist, and pragmatist philosophies were considered in addressing the research question.

3.2.1 Positivism

Positivism is a philosophical position of the natural scientist that sticks to the view that only accurate knowledge acquired through observation, including measurement, is credible. According to Collins (2010, p. 38), positivism as a philosophy:

> is in accordance with the empiricist view that knowledge stems from human experience. It has an atomistic, ontological view of the world as comprising discrete, observable elements and events that interact in an observable, determined and regular manner.

Positivists claim that it is possible to explain and predict human behaviours pertinent to cause and effect (May, 2001).

Positivist research method consists of experiment, observation and survey techniques. Positivists argue that the observer is separate from the entities that are subject to observation (Johnson and Onwuegbuzie, 2004). They are more likely to use the deductive approach, which involves developing a theory that is tested. In a deductive approach, the researcher remains distant and independent of what is being researched (Collins, 2010).
According to Johnson and Onwuegbuzie (2004), positivists advocate that researchers

should be unbiased, emotionally detached and uninvolved with the entities being studied, and test or empirically justify their stated hypotheses. This eliminates the possibility of human interests within the study, by restricting the researcher to data gathering and analysis in an objective manner; the researcher is independent from the study. The research findings are usually observable and quantifiable and may result in law-like generations akin to those made by physical and natural scientists (Remenyi et al., 1998; Saunders et al., 2009). The collected data is statistically analysed to obtain results and the hypothesis is proved empirically (Schiffman and Kanuk, 1997). The hypothesis will be accepted if it is proved, or rejected if disproved, in the experiment, leading to the further development of theory, which then can be tested by further research (Saunders et al., 2009). According to Crowther and Lancaster (2012), as a general rule, positivist studies usually adopt a deductive approach and are of the viewpoint that researchers need to focus on facts. Positivism is seen as a quantitative form of research, which searches for explanatory laws and it is most suited to studies that target a large number of respondents.

3.2.2 Interpretivism

Interpretivist research attempts to understand and explain human behaviour rather than generalise and predict causes and effects. According to Saunders et al., "Interpretivism advocates that it is necessary for the researcher to understand differences between humans in our role as social actors" (Saunders et al., 2009, p. 116). Interpretivists believe that reality is multiple and can be accessed through various well-thought-out ways. Interpretivism maintains "that reality, as well as our knowledge thereof, are social products and hence incapable of being understood independently of the social actors (including the researchers) that construct and make sense of that reality" (Orlikowski and Baroudi, 1990, p. 14).

Interpretivist research approaches are largely dependent on naturalistic methods that involve human interaction between researchers and their subjects of study in order to collaboratively construct a meaningful reality. Interpretivists typically adopt a qualitative approach in order to understand a phenomena or research subject. Qualitative research is exploratory, open-ended and aims at in-depth description. It comprises data collection, analysis, and interpretation through observation techniques. It is quite subjective, and information can be gathered using various methods, such as individual, in-depth interviews and focus groups.

Proponents of qualitative research method reject positivism and "argue for the superiority of constructivism, idealism, relativism, humanism, hermeneutics, and, sometimes, postmodernism" (Johnson and Onwuegbuzie, 2004, p. 14). They assert that their research methods allow closer involvement with their phenomena in a way that is not possible with quantitative research methods (Sechrest and Sidani, 1995).

3.2.3 Pragmatism

Pragmatism is the philosophical position that argues that the research approach is driven by the nature of the research question. Pragmatists are of the view that it is possible to work with both research paradigms (qualitative and quantitative research), including their associated methods in a single study, although one paradigm may likely be more suitable than the other for answering a particular research question.

Tashakkori and Teddlie (1998) believe that pragmatists consider the research question more important than the method employed or their way of thinking that would influence the method. This research philosophy suggests that the use of either qualitative or quantitative methods (or both) will largely depend on the research question. However, Bryman (1984) and Sandelowski (1993) pointed out that qualitative purists face the risk of losing perspective on the phenomena with which they are closely involved. As pointed out by Sechrest and Sidani (1995, p. 78), both research methods "are, after all, empirical, dependent on observation" and they also "describe their data, construct explanatory arguments from their data, and speculate about why the outcomes they observed happened as they did".

Johnson and Onwuegbuzie (2004) recognised the importance and usefulness of the synergy between qualitative and quantitative research methods known as the mixed methods research. Sechrest and Sidani also "emphasize that the two approaches are complementary; good science is characterized by methodological pluralism" (Sechrest and Sidani, 1995, p. 77). Mixed methods research does not replace either qualitative or quantitative approach, rather, it incorporates their strengths and minimises their weaknesses.

3.2.4 Selection of the Research Philosophy

Researchers including Bryman and Bell (2007) and Saunders (2009) favour using the method, which appears best suited to the research problem. They suggest using "whatever works" to answer the research question, recognising that every method has its limitations. Positivism is the paradigm position chosen for this research, as hypotheses will be tested in this study, and thus require complete objectivity in data collection and analysis.

3.3 Research Approach

The two major approaches to research are deductive and inductive. These research approaches are associated with different research philosophies. Proponents of Positivism identify themselves as affiliates of deduction while proponents of interpretivism typically associate themselves with induction (Saunders et al., 2009).

Deduction, as shown in Figure 3.1, is characterized by a "top-down" approach and usually begins with developing a theory from which a more specific hypothesis can be deduced and then tested to confirm or disconfirm the original theory through observation (Trochim, 2006).

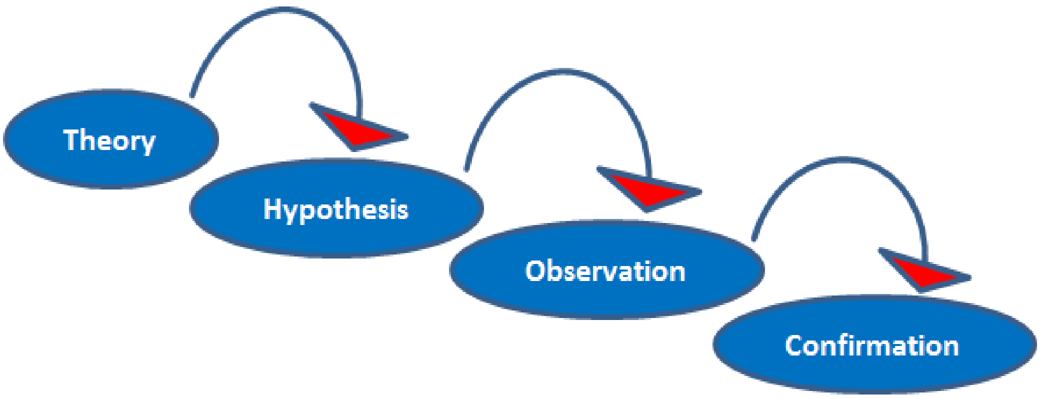

FIGURE 3.1 – The process of Deduction (Adapted from Trochim 2006)

Induction, as shown in Figure 3.2, is characterised by the "bottom-up" approach and usually starts with specific observations to formulate broader generalisations and theories using patterns and findings from analysed data (Trochim, 2006).

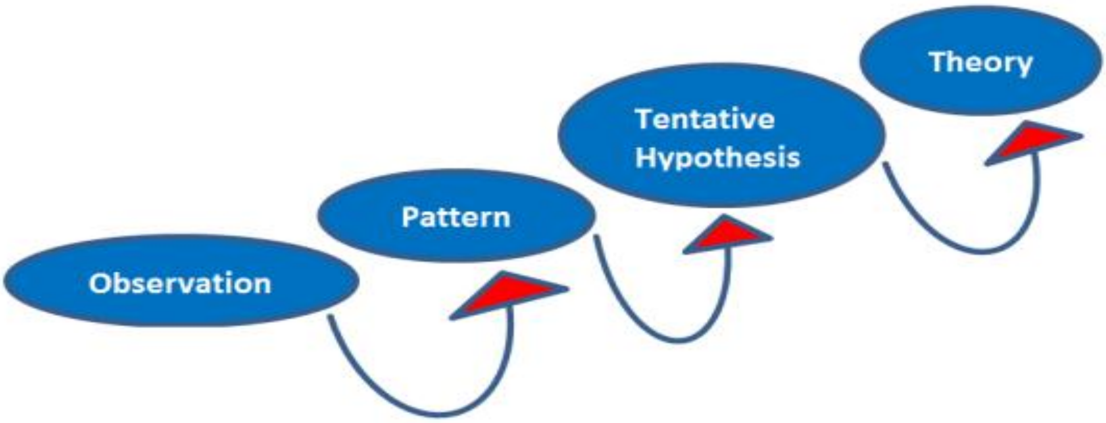

FIGURE 3.2 – The process of Induction (Adapted from Trochim 2006)

Of the two, deductive approach was selected for this study, as it enables testing of the hypotheses presented in sub-section 3.8.1, Hypothesis Development (pp. 44-47).

3.4 Research Strategy

The research strategies discussed by Saunders et al. (2009) are: experiment, survey, case study, action research, grounded theory, ethnography and archival research. Some of these strategies have been associated with either a deductive or inductive approach. However, Saunders et al. argue that no one strategy is better than the other and that what really matters most is the suitability of the strategy in answering the research question and meeting the set objectives. In other words, the choice of strategy should be driven by the research question, objectives, and practical considerations, such as time and money.

3.4.1 Selection of the Research Strategy

The option to adopt the ethnography approach for this research study was dismissed based on the grounds that it is very time consuming (Saunders et al., 2009) and lacks the objectivity, which is required for this study. Also, action research was not considered due to lack of objectivity. A case study approach was not considered for this study because it has a narrow focus, which makes generalisation impossible. In addition, it is costly, time consuming, and subjective. Grounded theory is for the purpose of building theory from data and therefore is not suitable for this study, which sets out to test hypotheses. Archival research was also not suitable for this study because it requires administrative records and documents as the principal source of data (Saunders et al., 2009).

Having reviewed all the strategies discussed by Saunders et al. (2009), an online survey was adopted as the research strategy primarily for its ubiquity. Online surveys provide a cost-effective, efficient and convenient way of collecting data from a large number of respondents dispersed over a large geographical area, thus making it possible for researchers to generalise their findings, reducing or eliminating geographical dependence. In the US, the National Science Foundation, in an attempt to determine the reasons for the poor performance of US students on math and science tests, adopted survey research for the 2000 National Survey, as it provided an efficient and systematic method for gathering data from a wide range of individuals and educational settings (Check and Schutt, 2012). Check and Schutt (2012) explained that surveys are popularly known for their versatility, efficiency, ability to form generalisation, and that although surveys are not suitable for in-depth studies, a well-designed survey can improve a researcher's understanding of almost any problem. According to Saunders et al. (2009), surveys are commonly used to answer "who", "what", "where", "how much" and "how many" questions and they are usually used for descriptive and exploratory research. Surveys are popularly used by the information systems research community for testing hypotheses (Newsted et al., 1998).

Although online surveys provide a convenient way of collecting data from a large number of participants, researchers are limited in control over participant selection, particularly with regards to demographics, such as age, gender etc. Response rates to online surveys are generally low, they can be difficult to design and they limit the number of questions that can be asked by the researcher (Saunders et al., 2009). To counter these drawbacks, the survey was designed in such a way that even with the lowest number of questions possible, it still supplied accurate and reliable information needed to accomplish the research objectives with confidence. To minimise the possibility of a low response to the survey, online forums with large memberships were selected as the target population for this survey.

3.5 Research Method

The two research method approaches considered for this study are the mixed method and mono method approach. The mono method approach was selected as it fulfils the objective of this research. Mono method approach, as the name suggest, uses only one type of method; quantitative or qualitative. It involves the use of “a single data collection technique and corresponding analysis procedures.” (Saunders et al., 2009, p. 151) as opposed to mixed method approach, which involves the use of “more than one data collection technique and analysis procedures” (Saunders et al., 2009, p. 151). In deciding whether to choose a quantitative or a qualitative method, the following were taken into consideration:

- The research question and the type of information needed to address the research question.

- The predominant method adopted in similar studies.

For the reasons explained below, a quantitative method was chosen for this research.

1. The research question: “What are the factors that influence consumer receptivity to in-home displays?” and the type of information needed to address the research question.

   Online survey, the chosen research strategy for this study (see section 3.4, Research Strategy, pp. 39-40), is one of the main methods of data collection in quantitative research. Surveys are commonly used to answer the “what” question in addition to the “who”, “where”, “how much” and “how many” questions (Saunders et al., 2009, p. 144). Sufficient information needed to accomplish the research objectives with confidence can be obtained quantitatively, without gaining in-depth insights (qualitative method) into participants’ views while still ensuring that the online questionnaire will provide accurate and reliable information.

2. Findings from a review of recent studies of technology adoption with particular emphasis on the methods adopted.

An extensive review of the literature on theoretical models of technology adoption was conducted to determine the predominant research method used in similar studies that set out to identify the factors that influence a technology adoption and use. A quantitative research method was the method of choice in most of these studies, in which hypotheses were tested and frameworks applied to address research questions on technology adoption and use. Prominent among them are studies by Vallerand et al. (1992), Adams et al. (1992), Davis (1993), Venkatesh and Davis (2000), Venkatesh et al. (2003), Brown and Venkatesh (2005), Brown et al. (2006) and Venkatesh et al. (2012); in addition to other studies by Fillion and Le Dinh (2008), Cameron (2010), Shroff (2011), Hsu and Yen (2012), Ghalandari (2012), and Raman and Don (2013).

3.6 Research Design

The Survey was presented in the form of a questionnaire (self-administered survey) created using an online survey tool from SurveyMonkey. The questionnaire was designed in accordance with the following recommendations made by Check and Schutt (2012):

- Well-structured.
- Succinct.
- Presented clear and interesting questions related to the study’s objective.
- Each section complemented other sections.

It was made up of three main parts and comprised sixteen questions. The first part of the questionnaire provided a brief description of an in-home display and outlined some of its key features. This part also contained the image of an in-home display to help improve participants' understanding.

The second part of the questionnaire contained most of the specific questions that addressed the research question. As pointed out by Check and Schutt (2012), there is no clear-cut formula for crafting a well-designed questionnaire. However, in designing the questionnaire, the main focus was to ensure all questions had a consistent meaning to respondents. Question specificity was considered an important part in creating the questionnaire, as it ensured all questions asked were clear, standardised and unambiguous. Double negatives (questions that use two or more negative phrases) and double barrelled (questions that ask two or more questions) questions were avoided and all questions were made short and simple. Questions that have a common theme and similar response choices were identified and put into a matrix format. The matrix format highlighted the common theme among the questions, thus encouraging participants to answer each question in relation to other questions in the matrix (Check and Schutt, 2012). Matrix questions helped to reduce the number of words required for each question, thus shortening the questionnaire. Closed-ended questions were used because they are more specific and therefore more likely to communicate similar meanings; a crucial requirement to achieve accurate results. Also data gathered from closed-ended questions lend themselves to statistical analysis, which is useful for hypothesis testing.

3.6.1 Refining and Testing the Questionnaire

"The only good question is a pretested question." (Check and Schutt, 2012, p. 163).

The questionnaire was first tried out on five colleagues who were asked to scrutinise each question to help detect flaws in the questionnaire in terms of grammar, clarity and format. All five colleagues identified two statements in a matrix question that obtained the same desired information but in different ways. A second problem identified was that one of the two statements had a word that seemed vague. Also two colleagues commented on the use of bold characters for the question about display options, which they felt was not necessary. Following a revision, the questionnaire was piloted on eight potential respondents who were not included in the main survey. They were asked to complete the questionnaire and provide feedback on the following:

- Time taken to complete the survey.
- Clarity of the questions.
- Suggest any improvements.

The survey instructions were no different from those issued to the real participants. All 8 respondents said it took just less than 10 minutes to complete the survey and that the questions were clearly understood. No improvements were suggested by all respondents.

3.7 Research Ethics

Survey research designs typically present fewer ethical problems than experimental or field research designs (Check and Schutt, 2012). However, prior to making the survey available to its target audience, ethical approval was requested from the Research Ethics Committee at the School of Computer Science and Statistics, Trinity College Dublin. The purpose of the Ethics Committee is to ensure the dignity, rights, safety and welfare of the survey participants is protected. An application form for Ethical approval was completed and submitted with the following documents to the Ethics Committee in March 2014:

- Letter to organisations.
- Informed consent form for organisations.
- Survey invitation.
- Completed ethics forms.
- Research proposal.
- PDF of Questionnaire (includes Information sheet for participants, Informed consent form for participants).

In line with the Research Ethics Committee guidelines, the first page of the online questionnaire was an information sheet explaining the background of the research and the survey procedure. Following this page was the informed consent form where potential respondents could easily decide to either participate in the study if they understood and accepted the declarations or opt out of the study if they declined. Following a review by the Ethics Committee, approval was granted on the 4th of April 2014.

3.8 Proposed Research Model

A review of recent literature on models of technology adoption suggests that there is no one size fits all framework. The proposed research model for this study is a modification of the UTAUT2 (Venkatesh et al., 2012) model chosen primarily for its applicability to a consumer context, hence its suitability for answering the research question: “what are the factors that influence consumer receptivity to in-home displays?”. As Figure 3.3 shows, the proposed research model incorporates two new constructs: aesthetics design and resistance to lifestyle change; it drops hedonic motivation and habit in UTAUT2. Four variables namely, household size, bill payer, age and familiarity are hypothesised to moderate the effect of these constructs on consumer receptivity to IHDs and potential to use. Studies have shown that greater familiarity can be gained through greater experience (Venkatesh et al., 2012). This may suggest that there is a positive relationship between familiarity and prior experience with the two processes occurring simultaneously.

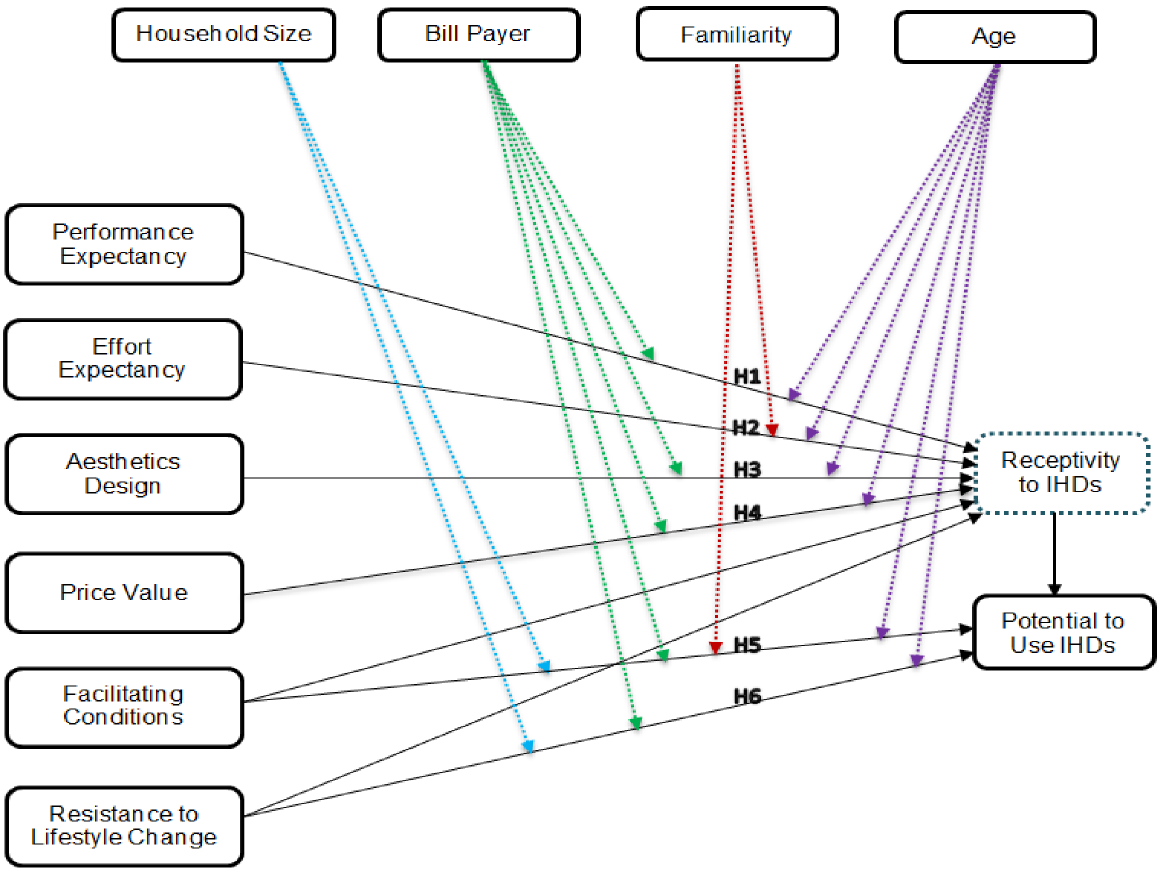

FIGURE 3.3 – Proposed Research Model (Adapted from Venkatesh et al. 2012)

3.8.1 Hypothesis Development

- Effect of Performance Expectancy (PE) on Consumer Receptivity to IHDs

  Previous research on technology acceptance has shown that performance expectancy is a key factor for predicting an individual’s acceptance of technology (Davis et al., 1992; Venkatesh and Davis, 2000; Taylor and Todd, 2001; Venkatesh et al., 2003). PE as defined by Venkatesh et al. (2012, p. 159) is “the degree to which using a technology will provide benefits to consumers". The main benefit consumers derive from using IHDs is a reduction in energy use, which translates into lower energy bills. From the viewpoint of the relationship between age and income, it is expected that young and old adults would be more motivated to conserve energy in order to save money on bills than middle-aged people (Semenik et al., 1982). Therefore, it can be argued that PE will have a stronger influence on younger and older people's receptivity to IHDs than among middle-aged people. Semenik et al.'s argument contradicts findings of a previous study by Morrison and Gladhart (1976). According to Morrison and Gladhart, generally, middle-aged families particularly those with children consume more energy and are therefore more likely to conserve energy. However, a study on household energy conservation patterns in Greece by Sardianou (2005) showed a decrease in the energy conserving actions in older adults.

Hypothesis 1: *Age will moderate the influence of performance expectancy (PE) on consumer receptivity to IHDs to the extent that it will be stronger among younger and older adults.*

- Effect of Effort Expectancy (EE) on Consumer Receptivity to IHDs

Effort expectancy "is the degree of ease associated with consumers' use of technology" (Venkatesh et al., 2012, p. 159). Previous studies have shown that EE has a positive effect on consumers' acceptance and use of technology (Venkatesh et al., 2003; Ghalandari, 2012; Raman and Don, 2013). Evidence from functional neuroimaging and behavioural studies suggest that cognitive function deteriorates more steeply after the age of fifty than from early adulthood (Smyth, 2009). This may suggest that perceived effort of learning increases with age.

Several studies have revealed that technology familiarity has a positive relationship with receptivity and intention to use (Christensen et al., 2001). Familiarity, as defined by Alba and Hutchinson (1987, p. 411), is "the number of product related experiences that have been accumulated by the consumer". According to Luhmann (1988), as cited by Du (2011), familiarity is knowledge that is acquired, based on a person's experience and previous interaction with a product. Increase in product familiarity leads to higher ability to successfully accomplish product related tasks by consumers (Alba and Hutchinson, 1987). Familiarity results in lower cognitive efforts required to accomplish tasks and improves a person's ability to analyse information (Alba and Hutchinson, 1987; Du, 2011). Research by Flavián et al. (2006)

demonstrated the positive influence familiarity has on consumers interest in a product.

Hypothesis 2: *Age and familiarity will moderate the influence of effort expectancy (EE) on consumer receptivity to IHDs to the extent that it will be stronger among older adults, particularly those who are less familiar with IHDs.*

- Effect of Aesthetics Design on Consumer Receptivity to IHDs

Several experimental studies on information visualisation have shown that aesthetics is a key factor in the acceptance, use and performance of a design (Lidwell et al., 2010). According to Lidwell et al., aesthetic designs appear easier to use and are more likely to be accepted and used regardless of whether they are really easier to use. Thus, it can be argued that people are more likely to develop positive attitudes toward a technology with aesthetic design than a similar technology with un-aesthetic design. Findings of studies by Reinecke et al. (2013) suggest that young people show more interest in aesthetics design than old people.

Hypothesis 3: *Age will moderate the influence of aesthetics design on consumer receptivity to IHDs to the extent that it will be stronger among young adults.*

- Effect of Price Value on Consumer Receptivity to IHDs

Price value as defined by Venkatesh et al. (2012, p. 161) is “consumers’ cognitive trade-off between the perceived benefits of the applications and the monetary cost for using them”. According to Venkatesh et al, price value has a positive influence on the adoption of a technology when the benefits of using the technology are perceived to outweigh the financial cost. Studies indicate that price value differs among age groups and social roles, the greatest levels being in older groups (Venkatesh et al., 2012).

Hypothesis 4: *Age will moderate the influence of price value on consumer receptivity to IHDs to the extent that it will be stronger among older adults.*

- Effect of Facilitating Conditions on Potential to Use IHDs

  Facilitating conditions "refer to consumers' perceptions of the resources and support available to perform a behaviour" (Venkatesh et al., 2012, p. 159). Some energy-saving programmes and initiatives by governments and utility providers offer free IHDs to households as part of ongoing efforts to promote energy efficiency. Considering the relationship between age and income, it is expected that young and old people who seek to drive down energy bills are more likely to use a free IHD than middle-aged people.

  Hypothesis 5: *Age and familiarity will moderate the influence of facilitating conditions on potential to use IHDs to the extent that it will be stronger among younger and older adults who are more familiar with IHDs.*

- Effect of Resistance to Lifestyle Change on Receptivity to IHDs

  Several studies have explored the role of social norms in determining energy efficient lifestyles. Shove (2003) argues that studies on energy efficiency should focus on social norms instead of individual consumption as they tend to lock consumers into consumption patterns akin to non-energy efficient lifestyles (EEA, 2013). Through social practices, people adopt energy consumption practices, which become habitual and routine as they age. Thus, it can be argued that households with more members will have a higher diversity of intra-household energy consumption practices. The expectation is that initiating a significant lifestyle change in households with more members will be very challenging and even more challenging to maintain in the long term, particularly among older adults.

  Hypothesis 6: *Age will moderate the influence of resistance to lifestyle change on potential to use IHDs to the extent that it will be stronger among older adults.*

3.9 Summary

The research philosophy adopted for this study was determined using the "Research Onion" suggested by Saunders et al*.* This adopted research philosophy is positivism, which subsequently determined the appropriateness of the research approach, research strategy, research method and data collection methods.

The proposed research model (see section 3.8, Proposed Research Model, pp. 43-47) for this study is a modification of the UTAUT2 (Venkatesh et al., 2012) model chosen primarily for its applicability to a consumer context. The constructs of the research model namely performance expectancy, effort expectancy, aesthetics design, price value, facilitating conditions and resistance to lifestyle change were used to formulate the hypotheses and design the online questionnaire, which sought to garner interesting and unbiased responses from participants. The following chapter presents the findings and analysis of this study.

4 Findings and Analysis

4.1 Introduction

This chapter presents the critical analysis and interpretation of the data gathered that ultimately answers the research question and proves or disproves the hypotheses tested in this study. The target population sample size for the survey was 100 adults aged 18 years and over living in the Republic of Ireland. By the end of the six week survey period, data had been collected from 109 respondents, but the initial suitability analysis revealed that some age categories were disproportionately represented. The survey was then re-opened for another two weeks in order to address the disproportionate representation by specifically targeting the poorly represented age categories.

4.2 Data Analysis

The data was collected through an online survey and then exported from SurveyMonkey to excel (XLS) and comma-separated values (CSV) files. Prior to exporting the data, incomplete responses (skipped all questions) were filtered out and the demographic information gathered was used to cross-tabulate and compare groups in order to provide important insights into how responses vary between these groups; this was accomplished using SurveyMonkey's analytical tools. The exported data in CSV format was then imported into an oracle database where further quantitative analysis was carried out using SQL aggregate functions with the "group by" clause. The results of the survey were also analysed using Microsoft excel and a statistical calculator available from StatPac Inc.

Prior to the analysis, the data was checked for errors. There were a total of 147 respondents in the survey, but only 141 were considered eligible for further analysis. Respondents in the following categories were excluded from the analysis:

- Did not agree to the survey consent information (1 respondent).
- Skipped all questions (5 respondents).

The results of the data analysis are presented as follows:

1. Demographic variables and prior experience with IHDs.
2. Determinants of IHD receptivity – based on the proposed research model.

4.3 Demographic Variables and Prior Experience with IHDs

Respondents were asked three demographic questions related to their age category, bill paying responsibility and number of household members. They were also asked to indicate their level of familiarity with IHDs, ranging from “Not at all familiar” to “Extremely familiar”.

4.3.1 Age Category

Which category below includes your age?

Initially, there were 109 respondents in the survey but the suitability analysis of the data revealed that the age categories were disproportionately represented with 18-30, 46-64, and 65+ having 9, 7 and 5 respondents respectively, while age category 31-45 had 80 respondents. Subsequent analysis following a two week extension of the survey showed that there was a significant increase in respondents in age categories 18-30 and 46-64 with additional 20 and 17 respondents respectively, while age category 65+ increased by just 2. The decision was then made to combine age categories 65+ and 46-64 into a single category (46+).

Of the 141 respondents considered eligible for further analysis, one respondent skipped this question. From the chart in Figure 4.1, it is clear that age category 18-30 and 46+ still appear to be disproportionately represented in comparison to age category 31-45. Age category 31-45 had the highest response with 57.1% (80 respondents), followed by category 46+ with 22.1% (31 respondents) while 18-30 category had 20.7% (29 respondents).

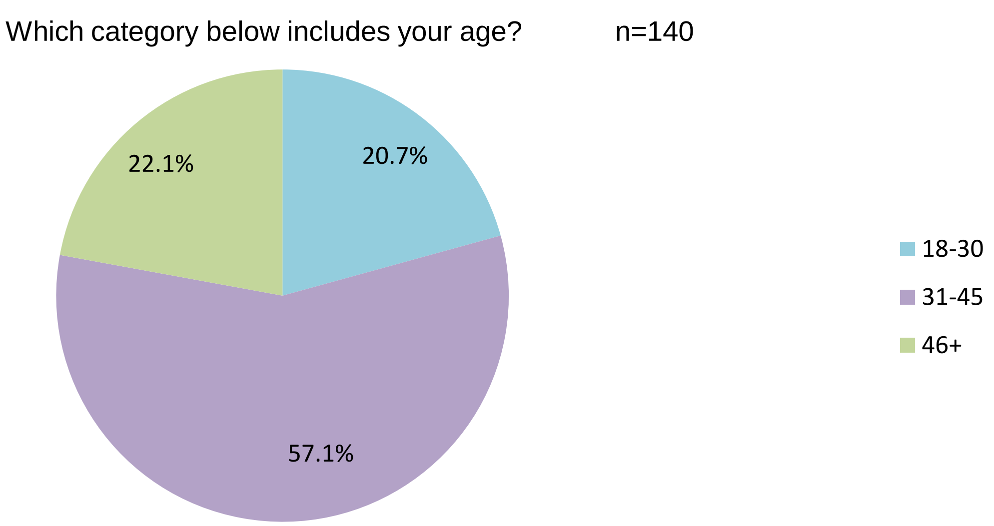

FIGURE 4.1 – Responses to age variable

4.3.2 Bill Payer

How much responsibility do you have for paying electricity bill for your household?

Respondents were asked to indicate their level of responsibility for paying electricity bill. As Figure 4.2 shows, 0.7% (1 respondent) of respondents indicated that they are not responsible for paying the electricity bill, while 99.3% (140 respondents) indicated that they have responsibility ranging from “Some of the responsibility” to “All of the responsibility”.

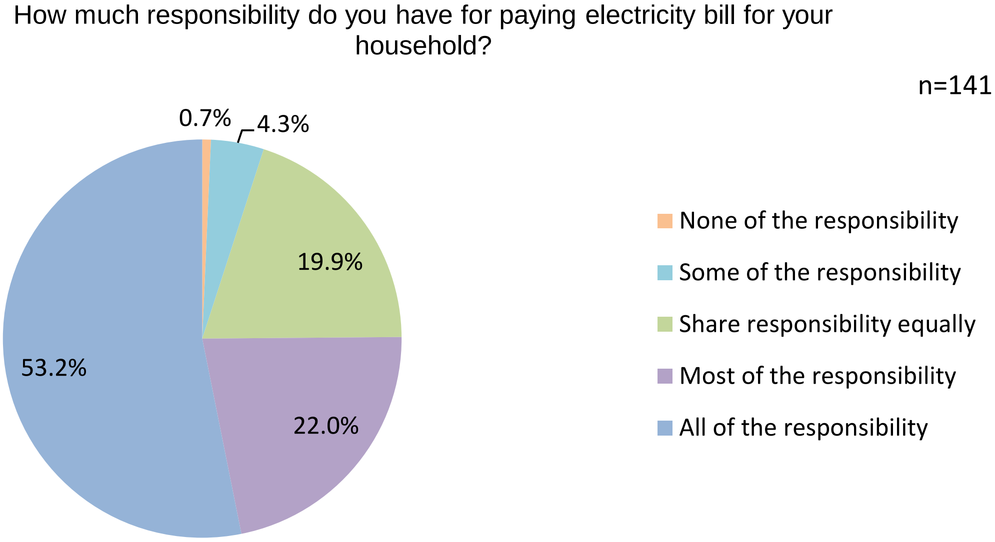

FIGURE 4.2 – Responses to “bill paying responsibility”

A two-dimensional cross-tabulation was used to analyse and compare the results for bill paying responsibility with the results for age category (shown in Table 4.1). Of the 141 eligible respondents, 1 failed to answer the age category question and was therefore excluded from the cross-tabulation analysis. From this data (Table 4.1), it can be seen that all respondents that belong to the 18-30 and 31-45 age categories are somehow responsible for paying bills. Of the 140 respondents selected for this analysis, only one person in the 46+ age category indicated that he/she has none of the responsibility for paying electricity bill.

A 5-point rating scale was applied to this question with weights ranging from 1 to 5 in the direction “None of the responsibility” to “All of the responsibility”. The mean (3.92) for age category 18-30 suggests that on average, respondents in this age category indicated that they equally share the responsibility for paying electricity bill. The mean for age category 31-45 and 46+ was 4.275 and 4.2258 respectively, which suggest that on average, respondents in these age categories indicated that they have most of the responsibility for paying electricity bill. The overall mean of 4.1403 suggests that on average, respondents indicated that they have most of the responsibility for paying electricity bill.

TABLE 4.1 – Bill Payer by Age Category

n=140

Responsibility for paying bills	18-30	31-45	46+	Response Count
None	0	0	1	**1**
Some	1	4	1	**6**
Share equally	7	19	2	**28**
Most	10	8	13	**31**
All	11	49	14	**74**
Total no. of respondents	**29**	**80**	**31**	**140**
Mean	**3.92**	**4.275**	**4.2258**	
SD	**0.4041**	**0.2326**	**0.3753**	

4.3.3 Household Size

How many people currently live in your household?

One respondent skipped this question and was therefore excluded from the analysis. From the data in the chart (Figure 4.3), it is clear that over 95% of respondents indicated that they live in a multi-member household (households with 2 or more members) while 4.3% (Figure 4.3) of respondents live in a single-member household (household with 1 member).

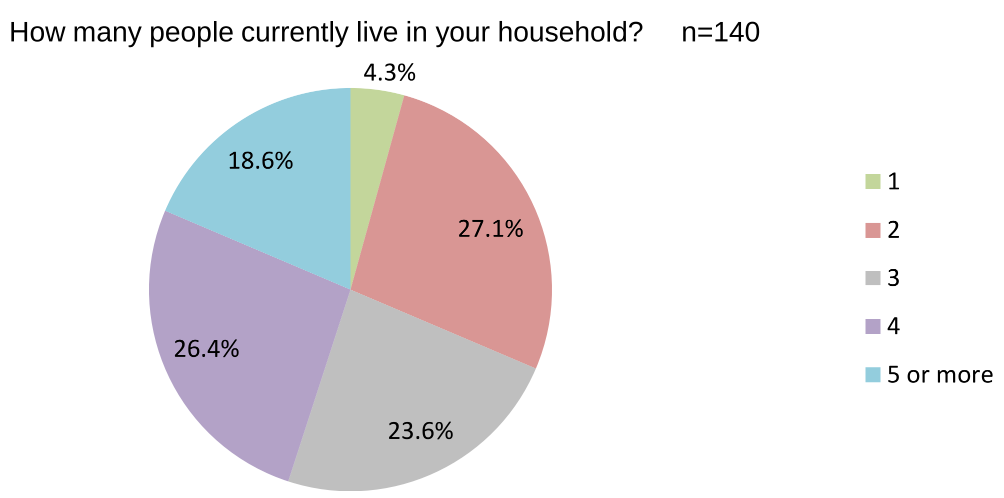

FIGURE 4.3 – Responses to household size

A two-dimensional cross-tabulation was employed to cross reference household size variable against bill payer variable; the results are shown in Table 4.2. It is apparent from the result in this table that all respondents living in multi-member households indicated responsibility for paying electricity bill ranging from “Some of the responsibility” to “All of the responsibility”. Furthermore, it can be seen that within each household size category, respondents with all of the responsibility for paying bills are highest in number.

TABLE 4.2 – Household size by Age Category

n=140

Responsibility for paying bills	Household size					
	1M	2M	3M	4M	= or > 5M	Response Count
None	1	0	0	0	0	**1**
Some	0	1	3	0	2	**6**
Share equally	0	9	6	10	3	**28**
Most	0	8	9	10	4	**31**
All	5	20	15	17	17	**74**
Total no. of respondents	**6**	**38**	**33**	**37**	**26**	**140**

4.3.4 Prior Experience with IHDs

The first part of the questionnaire provided a brief description of an IHD and outlined some of its key features. This was aimed at familiarising respondents with the basic features and benefits of an IHD. To help further improve their understanding, a labelled image of an IHD was also included in the questionnaire. Respondents were asked the following question in order to capture their level of familiarity with IHDs:

“*How familiar are you with In-Home Displays?”*

The majority of respondents who responded to this question indicated familiarity ranging from “Slightly familiar” to “Extremely familiar”. A 5-point rating scale was applied to this question with weights ranging from 1 to 5 in the direction “Not at all familiar” to “Extremely familiar”. The mean was 2.4752 and the standard deviation from the mean was 0.1330, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents are slightly familiar with IHDs.

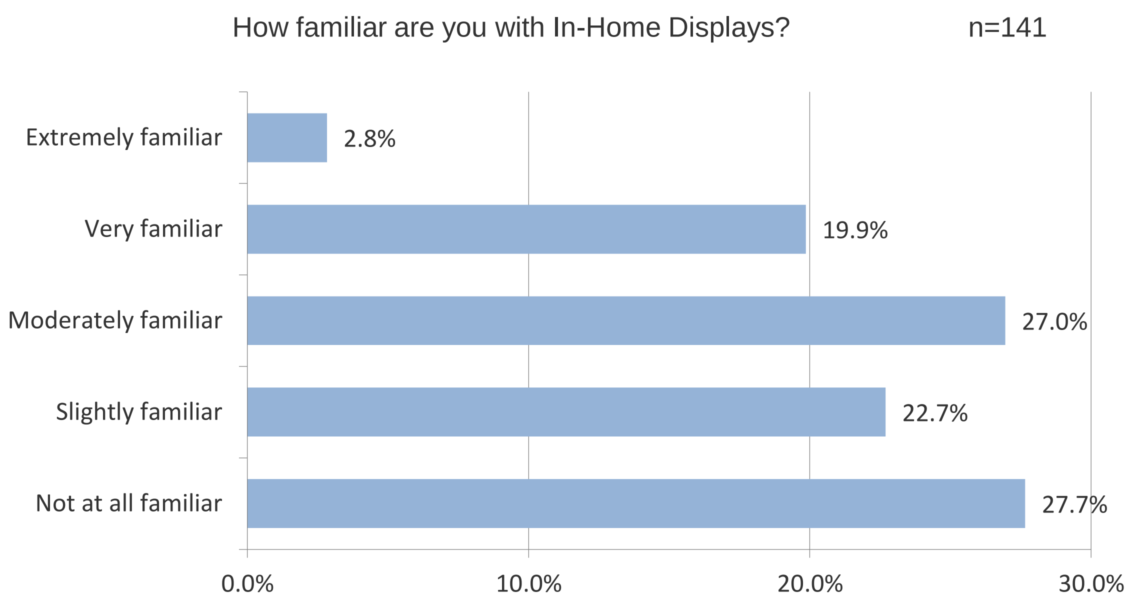

FIGURE 4.4 – Responses to familiarity with IHDs

As a follow-up question, respondents were asked:

"How interested would you be in buying an In-Home Display?"

From the data in the chart below (Figure 4.5), it can be seen that 18.4% of respondents indicated no interest in buying an IHD, while the majority (81.6%) indicated interest ranging from "Slightly interested" to "Extremely interested".

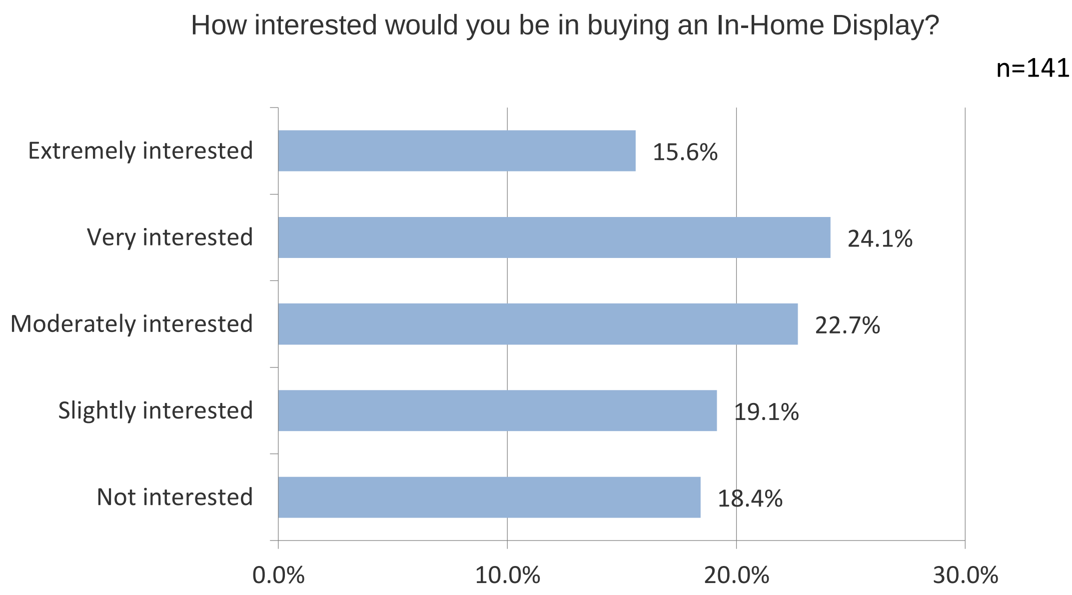

FIGURE 4.5 – Responses to Interest in buying an IHD

A 5-point rating scale was also applied to this question with weights ranging from 1 to 5 in the direction “Not interested” to “Extremely interested”. The mean was 2.9929 and the standard deviation from the mean was 0.1462, indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents are slightly interested in buying an IHD.

To gain insight into the relationship between familiarity and interest in buying an IHD, “interest in buying an IHD” was cross referenced against “familiarity with IHDs”. The results of the cross-tabulation analysis shown in Table 4.3 do not indicate that there is a relationship between the two variables. Interestingly, across all categories of “familiarity with IHDs”, with the exception of “Extremely familiar” (due to its low count) , “not at all familiar” category has the highest number of respondents (33) that indicated interest ranging from “Slightly interested” to “Extremely interested”.

TABLE 4.3 – “Interest in buying IHDs” by “familiarity with IHDs”

n=140

Interest in buying an IHD	Familiarity with IHDs					
	Not at all	Slightly	Moderately	Very	Extremely	Response Count
Not interested	6	5	7	7	1	**26**
Slightly interested	7	8	7	5	0	**27**
Moderately interested	10	8	9	5	0	**32**
Very interested	10	6	10	6	2	**34**
Extremely interested	6	5	5	5	1	**22**
Total no. of respondents	**39**	**32**	**38**	**28**	**4**	**141**

4.4 Determinants of IHD Receptivity

The proposed research model was customised from UTAUT2 to best fit in the context of consumer receptivity to IHDs by incorporating two new constructs namely aesthetics design and resistance to lifestyle change. In addition to the new constructs, four constructs from UTAUT2 namely performance expectancy, effort expectancy, price value, and facilitating conditions are also incorporated. These four constructs are considered to be important determinants of technology acceptance and use (Venkatesh et al., 2012). Respondents were asked questions in relation to these determinants. Individual differences, such as household size, bill payer, age and familiarity, are considered as the moderators of these determinants. However, due to the poor and disappointing representation of some categories in the bill payer and household size variables, the effect of these moderators as illustrated in Figure 3.3, section 3.8, Proposed Research Model (p. 44) could not be tested in this study. The analysis of the data, and the findings for each of the determinants, will be discussed in turn in the sub-sections that follow.

4.4.1 Performance Expectancy (PE)

A review of the literature suggested that IHDs have the potential to reduce electricity bills by up to 20 percent, primarily through the delivery of energy savings. Respondents were asked to indicate their likelihood to use an IHD based on its proven energy saving capabilities. In other words, would they use an IHD if it could provide them with feedback that could help them change their energy use behaviour, subsequently resulting in up to 20 percent savings on their electricity bills? To deliver energy savings of up to 20 percent or even more, IHDs must perform well enough to provide real-time, prompt, convenient and quality feedback on electrical energy consumption. This will enable consumers to make well informed decisions, thereby enabling them to take stronger action to reduce their energy consumption, which translates into a reduction in electricity bills.

The following question sought to find out the primary reason why respondents would use an IHD**:**

"What would be your primary reason for using an In-Home Display?"

Respondents had the option to select a single option from a list, via radio buttons, and to fill in their own answers simultaneously in a text entry box. Of the 141 respondents analysed, 1 completely skipped this question and another failed to choose from the list of options but entered "just curiosity" in the text entry box. Two other respondents also filled in the text entry box and also selected an answer choice from the list. Of the two, one entered "To see the breakdown of how energy is being consumed" while the other entered "to find out which appliances are wasting money & determine how I can become more efficient". However, both respondents selected the same answer choice from the list i.e. "To save money on my electricity bill". As Figure 4.6 shows, 1.4% of respondents indicated that their primary reason for using an IHD would be to reduce carbon emissions, a majority (75.5%) indicated that they would use an IHD to realise savings on electricity bills, while the remaining 23.0% indicated that they would use an IHD primarily to cut energy waste.

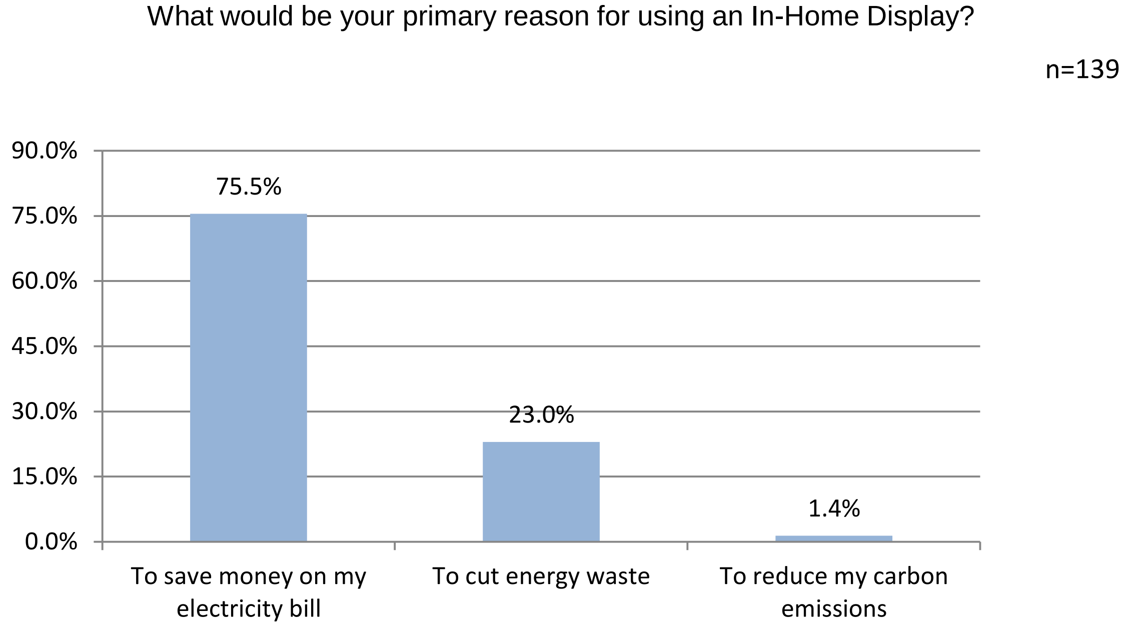

FIGURE 4.6 – Responses to “primary reason for using an IHD”

Respondents were asked to indicate their likelihood to use an IHD if it could yield up to 20 percent savings a month on electricity bills. In other words, if the energy saving capability (performance) of IHDs, which translates into savings on electricity bills, will influence their acceptance and use of IHDs.

“How likely would you be to use an In-Home Display if it could help you save up to 20 percent a month on your electricity bill?”

As Figure 4.7 shows, whilst a minority of respondents (6.4%) indicated that they are not at all likely to use an IHD, 93.6% indicated likelihood ranging from “Slightly likely” to “Completely likely”.

A 5-point rating scale was also applied to this question with weights ranging from 1 to 5 in the direction “Not at all likely” to “Completely likely”. The mean was 3.4823 and the standard deviation from the mean was 0.1577, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents are moderately likely to use an IHD if it could help them realise monthly savings of up to 20 percent on their electricity bills.

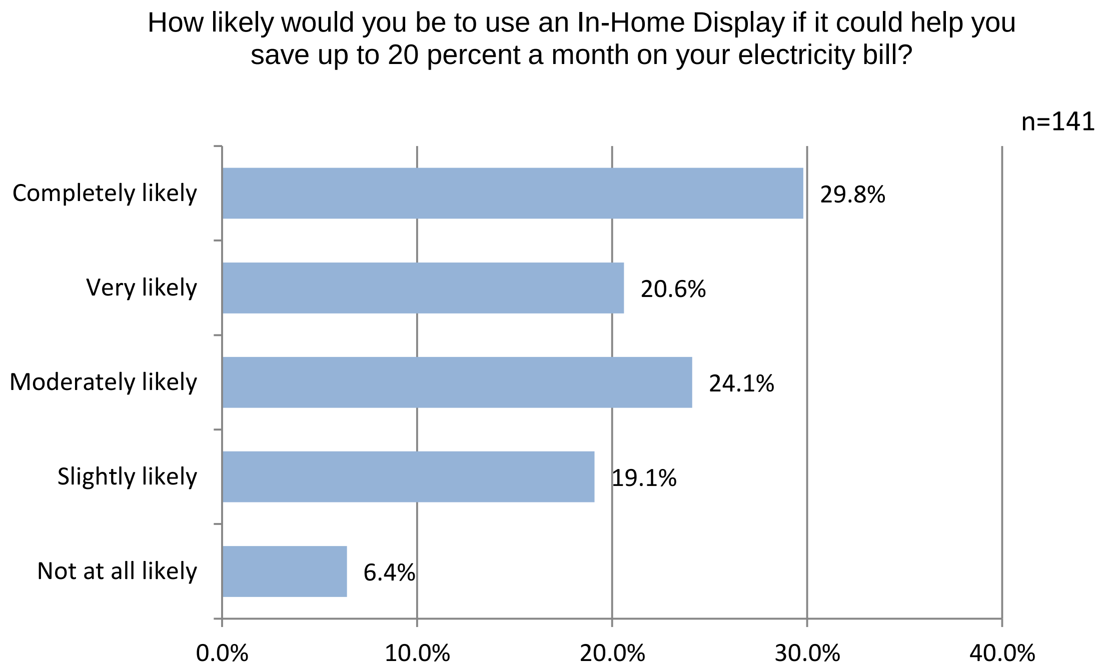

FIGURE 4.7 – Responses to use an IHD if it could yield 20% savings on electricity bill

Hypothesis 1: *Age will moderate the influence of performance expectancy on consumer receptivity to IHDs to the extent that it will be stronger among younger and older adults.*

Using cross-tabulation, the respondents' likelihood to use an IHD to realise up to 20 percent savings a month on electricity bills was cross-referenced against age category (Table 4.4). A 5-point rating scale was applied to this question with weights ranging from 1 to 5 in the direction "Not at all likely" to "Completely likely" and the mean and standard deviation were calculated for each age category. The most striking result to emerge from the cross-tabulation analysis is that the moderating effect of age on the influence of the energy saving capability of IHDs (Performance) appears to be stronger among respondents that belong to the youngest (18-30) and oldest (46+) age categories as revealed by the mean for all three age categories (Table 4.4).

TABLE 4.4 – Use IHD to achieve 20 percent savings by Age category

n=140

Use IHD to achieve 20% savings on electricity bill	18-30	31-45	46+	Response Count
Not at all likely	1	9	1	**11**
Slightly likely	5	22	2	**29**
Moderately likely	5	23	5	**33**
Very likely	7	12	7	**26**

Use IHD to achieve 20% savings on electricity bill	18-30	31-45	46+	Response Count
Completely likely	11	14	16	**41**
Total no. of respondents	**29**	**80**	**31**	**140**
Mean	**3.7586**	**3**	**4.1290**	
SD	**0.3664**	**0.1949**	**0.3710**	

To determine if the results are statistically significant, a Chi-square test was performed. The test returned a Chi-square statistic of 20.972, df (degree of freedom) of 8 and a p-value (probability of chance) of 0.0072. This result was deemed statistically significant as the p-value is less than $\alpha = 0.05$.

Therefore, H1 is supported, as age was statistically proven to be a significant moderator thereby rejecting the null hypothesis (H_0) that age will not moderate the influence of PE on receptivity to IHDs to the extent that it will be stronger among younger and older adults.

4.4.2 Effort Expectancy (EE)

Studies have shown that effort expectancy has a positive effect on consumers' acceptance and use of technology (Venkatesh et al., 2003; Ghalandari, 2012; Raman and Don, 2013). Evidence from other studies suggest that perceived effort of learning increases with age (Smyth, 2009), and that technology familiarity has a positive relationship with receptivity and intention to use (Christensen et al., 2001).

Respondents were asked to rate how each of the Likert statements (S1 and S2) in Table 4.5 would influence their buying choices, assuming they decide to buy an IHD. One respondent was excluded from the analysis for failing to rate S2. A 5-point Likert scale ranging from 1 to 5 was applied to each statement in the direction "Not at all influential" to "Extremely influential".

TABLE 4.5 – Statements on effort expectancy

	Assuming you decide to buy an In-Home Display, how will each of the following influence your choice?	Total
S1	It is easy to use	n=141
S2	It is easy to install	n=140

From the chart in Figure 4.8, it can be seen that for each rating level, there is a slight difference between the response percentages for statements S1 and S2. These results, although not surprising, are interesting to see nonetheless, indicating that for each statement, a majority of respondents may have chosen the same rating level, thus suggesting that both statements have similar effects (effort expectancy) on the buying choice of respondents.

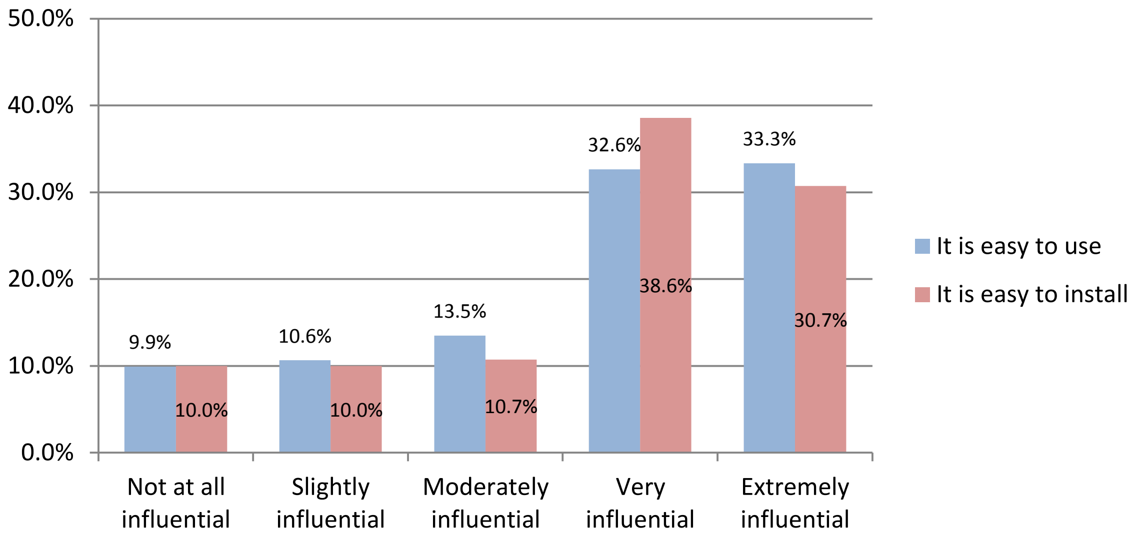

FIGURE 4.8 – Responses to effort expectancy

A 5-point Likert scale ranging from 1 to 5 was applied in the direction “Not at all influential” to “Extremely influential”. The overall mean was 3.6940 and the standard deviation from the mean was 0.1115, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that both statements would moderately influence their buying choice.

Hypothesis 2: *Age and familiarity will moderate the influence of effort expectancy on consumer receptivity to IHDs to the extent that it will be stronger among older adults, particularly those who are less familiar with IHDs.*

Each statement in Table 4.5 (p. 59) was cross-referenced against age category and a 5-point Likert scale ranging from 1 to 5 was applied to the statements in the direction “Not at all influential” to “Extremely influential”. It is apparent from the mean in Table 4.6 and 4.7 that the effect of both statements is strongest among respondents that belong to the 46+ age category; not surprising, but certainly interesting to see it revealed in the data.

TABLE 4.6 – “Ease of use” by age category

n-140

Ease of use	18-30	31-45	46+	Total
Not at all influential	6	7	1	**14**
Slightly influential	5	7	3	**15**
Moderately influential	7	9	2	**18**
Very influential	6	34	6	**46**
Extremely influential	5	23	19	**47**
Total	**29**	**80**	**31**	**140**
Mean	**2.9655**	**3.7375**	**4.2581**	
SD	**0.3254**	**0.2175**	**0.3767**	

TABLE 4.7 – “Ease of installation” by age category

n=139

Ease of installation	18-30	31-45	46+	Total
Not at all influential	5	7	2	**14**
Slightly influential	7	5	2	**14**
Moderately influential	5	9	1	**15**
Very influential	7	38	8	**53**
Extremely influential	5	20	18	**43**
Total	**29**	**79**	**31**	**139**
Mean	**3**	**3.7468**	**4.2258**	
SD	**0.3273**	**0.2192**	**0.3753**	

To determine the statistical significance of the results, further analysis with a Chi-square test was performed. The Chi-square test for the cross-tab results in Table 4.6 returned a Chi-square statistic of 25.597, df (degree of freedom) of 8 and a p-value (probability of chance) of 0.0012. The Chi-square test for the cross-tab results in Table 4.7 returned a Chi-square statistic of 26.709, df (degree of freedom) of 8 and a p-value (probability of chance) of 0.0008. Both results were deemed statistically significant as the p-values are less than $\alpha = 0.05$.

To determine the moderating effect of familiarity on effort expectancy, further analysis was carried out using SQL aggregate functions with the “group by” clause to provide the results shown in Table 4.8 and 4.9. It is evident from the SQL results shown in both tables that there is a correlation between the variables. As Table 4.8 shows, this correlation appears strongest among respondents aged 46+ who indicated familiarity ranging from “Not at all familiar” to “Slightly familiar”.

TABLE 4.8 – “Familiarity with IHDs” by age category by “ease of use”

n=140

Familiarity	Age category	Not at all influential	Slightly influential	Moderately influential	Very influential	Extremely Influential	No. of responses
Not at all							
	18-30	0	0	3	1	2	6
	31-45	4	2	2	12	8	28
	46+	0	0	0	0	5	5
		4	**2**	**5**	**13**	**15**	**39**
Slightly							
	18-30	1	2	1	1	1	6
	31-45	1	1	3	11	4	20
	46+	0	0	1	0	5	6
		2	**3**	**5**	**12**	**10**	**32**
Moderately							
	18-30	0	1	1	2	1	5
	31-45	1	3	3	10	7	24
	46+	0	0	0	5	3	8
		1	**4**	**4**	**17**	**11**	**37**
Very							
	18-30	5	2	2	1	1	11
	31-45	1	1	1	1	3	7
	46+	0	0	0	3	7	10
		6	**3**	**3**	**5**	**11**	**28**
Extremely							
	18-30	0	0	0	1	0	1
	31-45	0	0	0	0	1	1
	46+	0	0	0	2	0	2
		0	**0**	**0**	**3**	**1**	**4**
Total		**13**	**12**	**17**	**50**	**48**	**140**

TABLE 4.9 – “Familiarity with IHDs” by age category by “ease of installation”

n=139

Familiarity	Age category	Not at all influential	Slightly influential	Moderately influential	Very influential	Extremely Influential	No. of responses
Not at all							
	18-30	3	0	0	2	1	6
	31-45	2	2	2	15	6	27
	46+	0	0	0	2	3	5
		5	**2**	**2**	**19**	**10**	**38**
Slightly							
	18-30	1	1	1	2	1	6
	31-45	1	1	1	13	4	20
	46+	0	0	0	2	4	6
		2	**2**	**2**	**17**	**9**	**32**
Moderately							
	18-30	1	0	2	2	0	5
	31-45	2	2	4	9	7	24
	46+	0	0	0	4	4	8
		3	**2**	**6**	**15**	**11**	**37**
Very							
	18-30	0	6	2	1	2	11
	31-45	2	0	1	1	3	7
	46+	0	0	1	3	6	10
		2	**6**	**4**	**5**	**11**	**28**
Extremely							

Familiarity	Age category	Not at all influential	Slightly influential	Moderately influential	Very influential	Extremely Influential	No. of responses
	18-30	0	0	0	0	1	1
	31-45	0	0	1	0	0	1
	46+	0	0	0	0	2	2
		0	**0**	**1**	**0**	**3**	**4**
Total		**12**	**12**	**15**	**56**	**44**	**139**

Taken together, these results support H2, thereby rejecting the null hypothesis (H_0) that age and familiarity will not moderate the influence of effort expectancy on receptivity to IHDs to the extent that it will be stronger among older adults, particularly those who are less familiar with IHDs.

4.4.3 Aesthetics Design

Studies suggest that people are more likely to develop positive attitudes toward a technology with aesthetic design than a similar technology with un-aesthetic design (Lidwell et al., 2010). Findings of studies by Reinecke et al. (2013) suggest that young people show more interest in aesthetics than old people.

Respondents were asked to rate how the following Likert statements in Table 4.10 will influence their buying choices assuming they decide to buy an IHD.

TABLE 4.10 – Likert statements on aesthetics design and usability

	Assuming you decide to buy an In-Home Display, how will each of the following influence your choice?	Total
S1	It is controlled via buttons, a touch screen, or additional software	n=140
S2	It has an artistic beauty or pleasing appearance (aesthetics)	n=141

From the data in Figure 4.9, it can be seen that in response to S1, 7.1% of respondents indicated that it would have no influence on their buying choice, while a majority of respondents (92.9%) indicated influence ranging from “Slightly influential” to “Extremely influential”. This was similar in the case of S2 where a majority of respondents (84.4%) also indicated influence ranging from “Slightly influential” to “Extremely influential”, while 15.6% of respondents indicated that artistic beauty or pleasing appearance has no influence at all on their buying choice of an IHD.

A 5-point Likert scale ranging from 1 to 5 was applied in the direction “Not at all influential” to “Extremely influential”. The overall mean was 3.203 and the standard deviation from the mean was 0.1070, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that the aesthetic design of an IHD would moderately influence their buying choice.

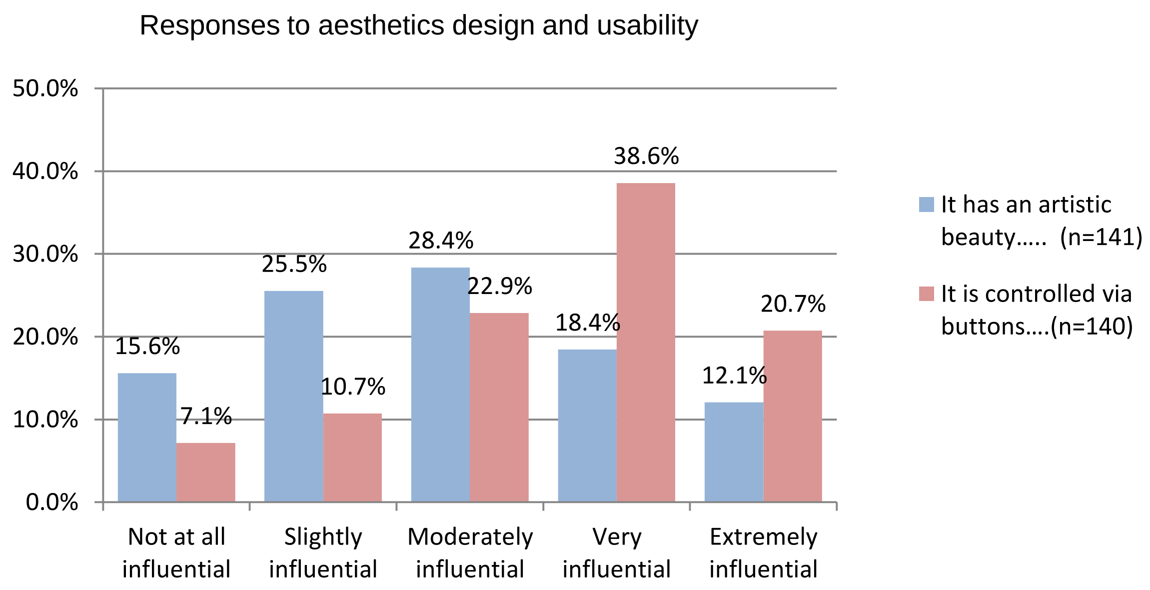

FIGURE 4.9 – Responses to aesthetics design and usability

Respondents were also asked to choose their preferred display format from three images that represent display formats of IHDs. Of the three, the first two (Graph and Chart) had a pleasing appearance while the third (Text) looked plain. As Figure 4.10 shows, the "Chart" display format was the most preferred with 40.4%, and "Graph" was the least preferred with 24.1%. Surprisingly, the "Text" display format was the second most preferred display format.

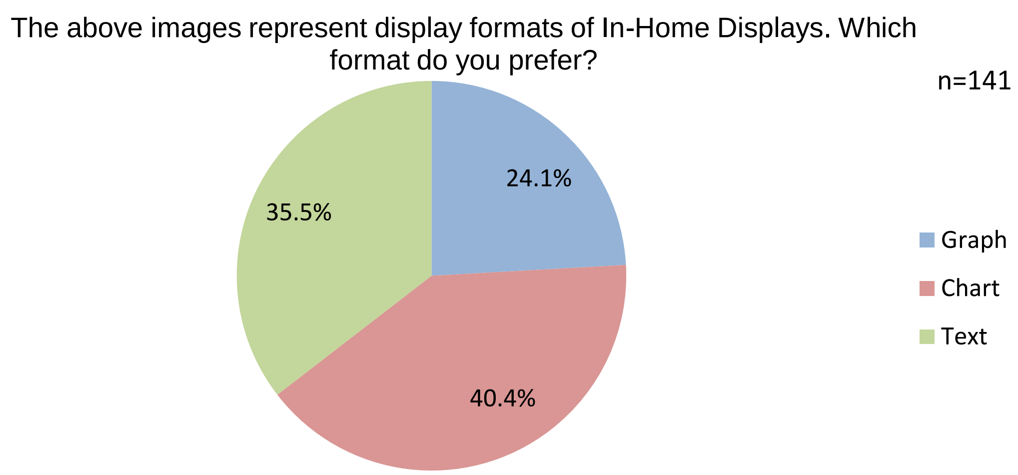

FIGURE 4.10 – Responses to display formats

Hypothesis 3: *Age will moderate the influence of aesthetics design on consumer receptivity to IHDs to the extent that it will be stronger among young adults.*

To determine the moderating effect of age on the influence of aesthetics design on receptivity to IHDs, the Likert statements in Table 4.10 (p. 63) and “display format” were cross-referenced against age (Table 4.11, 4.12, and 4.14) and a Chi-square test was performed to test for statistical significance. The mean and standard deviation for the responses to the Likert statements for each age category was also calculated; the results are presented in Table 4.13.

TABLE 4.11 – S1 by age category

n=139

	18-30	31-45	46+	Total
Not at all influential	1	8	5	**14**
Slightly influential	2	20	8	**30**
Moderately influential	6	30	8	**44**
Very influential	12	14	7	**33**
Extremely influential	7	8	3	**18**
Total	**28**	**80**	**31**	**139**

TABLE 4.12 – S2 by age category

n=140

	18-30	31-45	46+	Total
Not at all influential	2	14	6	**22**
Slightly influential	2	28	5	**35**
Moderately influential	7	24	9	**40**
Very influential	8	12	6	**26**
Extremely influential	10	2	5	**17**
Total	**29**	**80**	**31**	**140**

It is apparent from the overall mean results in Table 4.13 that among the age categories, the buying choice of category 18-30 was influenced the most by both statements with an overall mean of 3.7721, thus suggesting that on average, respondents that belong to this age category indicated that aesthetics design would moderately influence their buying choice of IHDs.

TABLE 4.13 – Mean and Standard Deviation of response groups (aesthetic design)

		It is controlled via buttons, a touch screen ……	It has an artistic beauty or pleasing….	Overall mean
Mean	18-30	3.7857	3.7586	**3.7721**
SD		0.3744	0.3664	
Mean	31-45	2.925	2.5	**2.7125**
SD		0.1924	0.1779	
Mean	46 or over	2.8387	2.9677	**2.9032**
SD		0.3076	0.3145	

From the data in Table 4.14, it is clear that a majority of respondents in the 18-30 age category prefer the aesthetically pleasing graph and chart images to the plain text image. Interestingly, of the 4 respondents in the 18-30 age category who indicated their preference for the "Text" image, 2 indicated that "artistic beauty or pleasing appearance" would not influence their buying choice while the other 2 indicated that it would slightly influence their buying choice (Table 4.12); this was verified using SQL queries.

TABLE 4.14 – "Display format" by age category

n=140

Display Format	18-30	31-45	46 or over	Total
Graph	12	16	6	**22**
Chart	13	35	9	**35**
Text	4	29	16	**40**
Total	**29**	**80**	**31**	**140**

Further analysis using a Chi-square test was performed to test for statistical significance. For the results in table 4.11, the Chi-square test returned a Chi-square statistic of 17.395, df (degree of freedom) of 8 and a p-value (probability of chance) of 0.0262.

The Chi-square test for the results in Table 4.12 returned a Chi-square statistic of 30.375, df (degree of freedom) of 8 and a p-value (probability of chance) of 0.0002.

The Chi-square test for the results in Table 4.14 returned a Chi-square statistic of 11.952, df (degree of freedom) of 4 and a p-value (probability of chance) of 0.0177.

All three results were deemed statistically significant as their p-values are less than α = 0.05. Taken together, these results support H3 thereby rejecting the null hypothesis (H_0)

that age will not moderate the influence of aesthetics design on receptivity to IHDs to the extent that it will be stronger among younger adults.

4.4.4 Price Value

Studies have shown that price value has a positive impact on the uptake of a technology when the financial cost is overshadowed by the expected benefits of using the technology, and that its effect differs among age groups and social roles, the greatest levels being in older groups.

Respondents were asked to indicate the usefulness of the type of feedback provided by an IHD (see Table 4.15). Of the 141 respondents analysed, 6 failed to rate some of the statements, 1 respondent in particular failed to rate 3 of the statements.

TABLE 4.15 – Usefulness of information displayed on an IHD

	whole house energy Consumption + cost (S1)	whole house + appliance-level energy…(S2)	Historical usage for the past day, week and month (S3)	Alerts me if an appliance is left on (S4)
Not useful	4	2	5	2
Slightly useful	4	2	10	10
Moderately useful	19	6	33	19
Very useful	71	64	62	54
Extremely useful	42	63	29	55
Total	**140**	**137**	**139**	**140**
Mean	**4.0214**	**4.3431**	**3.7194**	**4.0714**
SD	**0.1701**	**0.1787**	**0.1642**	**0.1711**

A 5-point Likert scale ranging from 1 to 5 was applied to each statement in the direction "Not useful" to "Extremely useful". The overall mean for the Likert statements was 4.0378 and the standard deviation from the mean was 0.0853, thus indicating that 68% of the responses are close to the mean and also suggesting that, on average, respondents indicated that the feedback would be very useful.

Respondents were also asked to indicate how the Likert statement in Table 4.16 would influence their buying choice of an IHD assuming they decide to purchase one. Of the 141 respondents analysed, 1 failed to rate the statement.

TABLE 4.16 – "It can perform additional functions..."

n=140

	It can perform additional functions (e.g., weather or tips on energy savings)
Not at all influential	25
Slightly influential	28
Moderately influential	32
Very influential	29
Extremely influential	26
Total	**140**
Mean	**3.0214**
SD	**0.1474**

A 5-point Likert scale ranging from 1 to 5 was applied to the statement in the direction "Not at all influential" to "Extremely influential". The mean was 3.0214 and the standard deviation from the mean was 0.1474, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that additional functional capabilities, such as weather information or tips on energy savings, would moderately influence their buying choice.

When asked how much they would be willing to pay for an IHD, 25% of respondents indicated that they would be willing to pay less than €40 (Figure 4.11), while 75% indicated they would be willing to pay over €40. A 5-point scale ranging from 1 to 5 was applied in the direction "less than €40" to "Over €100". The mean was 2.443 and the standard deviation from the mean was 0.1525, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that they would be willing to pay between €40 and €60 for an IHD.

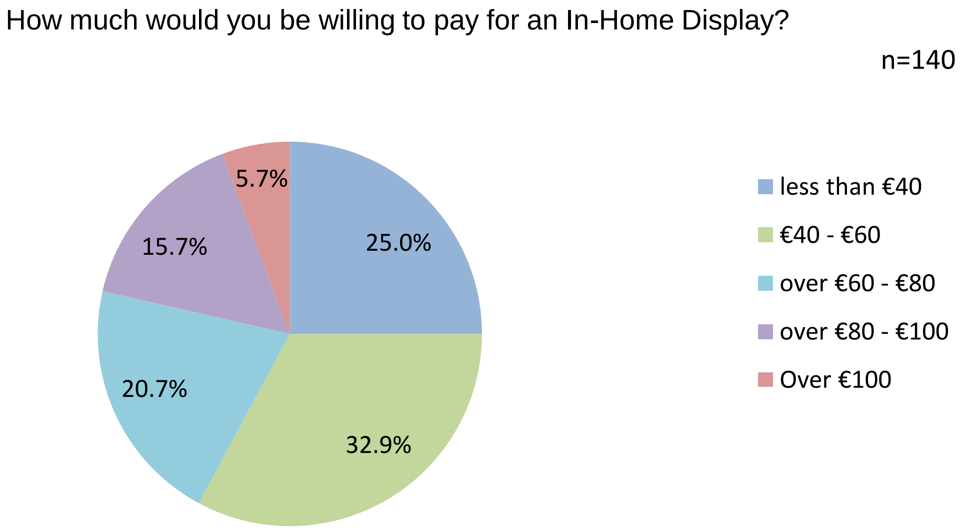

FIGURE 4.11 – Responses to "how much are you willing to pay for an IHD"

Hypothesis 4: *Age will moderate the influence of price value on consumer receptivity to IHDs to the extent that it will be stronger among older adults.*

To determine the moderating effect of age on the influence of price value on receptivity to IHDs, further analysis using cross-tabulation and a Chi-square test was performed. As Table 4.17 shows, the mean and standard deviation suggest that on average, respondents that belong to age category 46+ indicated that they would be willing to pay between €40 and €60 for an IHD.

TABLE 4.17 – Willing to pay by age category

n=139

Scale	Price range	18-30	31-45	46+	Total
1	less than €40	7	16	12	**35**
2	€40 - €60	6	33	6	**45**
3	over €60 - €80	8	16	5	**29**
4	over €80 - €100	6	10	6	**22**
5	Over €100	2	4	2	**8**
	Mean	**2.6552**	**2.4051**	**2.3548**	
	Standard Deviation	**0.3079**	**0.1756**	**0.2802**	

The Chi-square test for the cross-tab results (Table 4.17) returned a Chi-square statistic of 10.340, df (degree of freedom) of 8 and a p-value (probability of chance) of 0.2420. This result was deemed statistically insignificant as the p-value is greater than $\alpha = 0.05$.

Therefore, the null hypothesis (H_0) that age will not moderate the influence of price value on receptivity to IHDs to the extent that it will be stronger among older people is not rejected.

4.4.5 Facilitating Conditions

Some energy-saving programmes and initiatives offer free IHDs to households as part of ongoing efforts to facilitate energy efficiency improvements in the residential sector. Bearing in mind the relationship between age and income, one would expect that young and old people are more likely to use a free IHD to drive down energy bills.

Respondents were asked to indicate their likelihood to use an IHD, if they were offered one for free. As Figure 4.12 shows, a minority of respondents (7.9%) indicated that they would not likely use an IHD for free, while 92.1% indicated likelihood ranging from "Slightly likely" to "Completely likely". A 5-point rating scale was applied to this question with weights ranging from 1 to 5 in the direction "Slightly likely" to "Completely likely". The mean was 3.8031 and the standard deviation from the mean was 0.1737, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that they would moderately likely use an IHD for free.

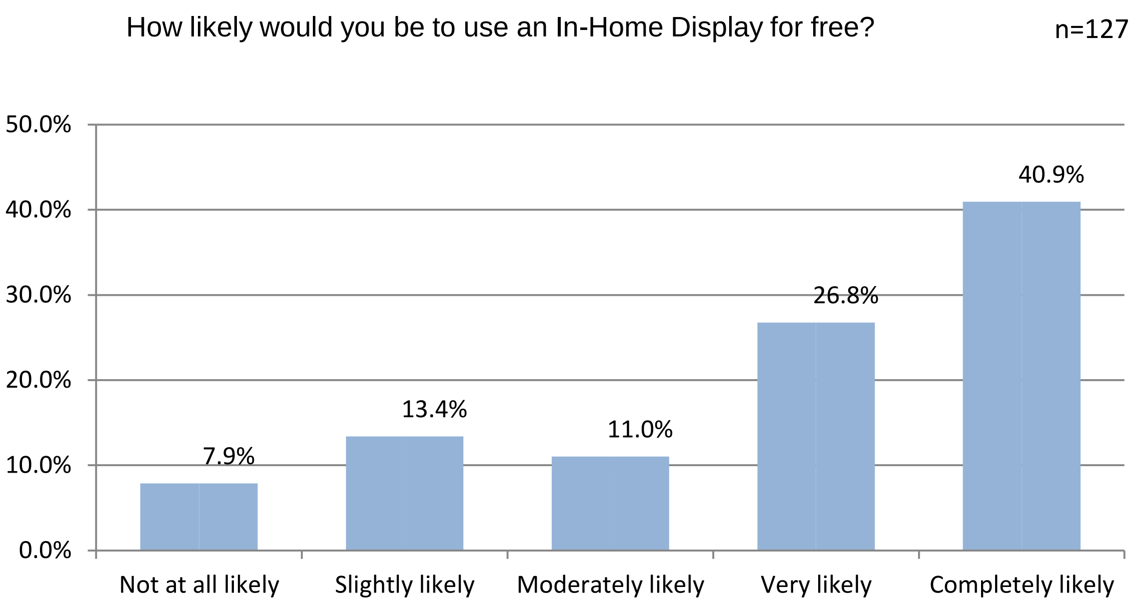

FIGURE 4.12 – Responses to likelihood to use an IHD for free

Hypothesis 5: *Age and familiarity will moderate the influence of facilitating conditions on potential to use IHDs to the extent that it will be stronger among younger and older adults who are more familiar with IHDs.*

Using cross-tabulation, "likelihood to use an IHD for free" was cross-referenced against age category. From the data (mean and standard deviation) in Table 4.18, it can be seen that regardless of age, respondents indicated that they are moderately likely to use an IHD for free.

TABLE 4.18 – Use for free by Age category

n=126

Use IHD for free	Age Category			
	18-30	31-45	46+	Response Count
Not at all likely	1	5	4	**10**
Slightly likely	5	6	6	**17**

Use IHD for free	Age Category			
Moderately likely	1	8	5	**14**
Very likely	7	18	8	**33**
Completely likely	11	34	7	**52**
Total no. of respondents	**25**	**71**	**30**	**126**
Mean	**3.88**	**3.9859**	**3.2667**	
Standard Deviation	**0.4021**	**0.2386**	**0.3356**	

Further statistical analysis was performed using a Chi-square test to determine the statistical significance of the results. The Chi-square test returned a Chi-square statistic of 9.887, df (degree of freedom) of 8 and a p-value (probability of chance) of 0.2730. This result was deemed statistically insignificant as the p-value is greater than $\alpha = 0.05$. Therefore, the test is inconclusive, as the null hypothesis (H_0) is not rejected and the alternate hypothesis (H5) is not supported.

"Use IHD for free" was cross-referenced against familiarity as shown in Table 4.19. From the data in the table, it can be seen that respondents with familiarity ranging from "Not at all familiar" to "Moderately familiar" indicated that they are moderately likely to use an IHD for free, respondents with familiarity ranging from "Very familiar" to "Extremely familiar" indicated that they are very likely to use an IHD for free. Further statistical analysis was not possible with the Chi-square test, as the number of cells with less than 5 was more than 25% of the cells (a limitation of the Chi-square test).

TABLE 4.19 – Use for free by familiarity

n=127

Use IHD for free	Familiarity with IHDs				
	Not at all	Slightly	Moderately	Very	Extremely
Not at all likely	3	1	6	0	0
Slightly likely	4	6	3	4	0
Moderately likely	2	3	5	3	0
Very likely	8	7	12	6	2
Completely likely	15	13	9	13	2
Total no. of respondents	**32**	**30**	**35**	**26**	**4**
Mean	**3.875**	**3.8333**	**3.4286**	**4.0769**	**4.5**
Standard Deviation	**0.3536**	**0.3636**	**0.3176**	**0.4038**	**1.2247**

4.4.6 Resistance to Lifestyle Change

Studies have shown that through social practices, people adopt energy consumption practices, which become habitual and routine as they age. To be energy efficient, consumers need to fulfil their daily needs with the minimum amount of energy possible. Thus, the expectation is that energy efficiency measures that necessitate a change in lifestyle will be difficult to implement in households with older adults.

The following statements in Table 4.20 were asked in the online survey to determine how often respondents engage in basic energy-efficient behaviours in their day-to-day activities. The 7-category Likert scale was reduced down to five by excluding the “Don’t know” and “N/A” (Not Applicable) categories.

TABLE 4.20 – Energy-saving behaviour statements

	How often do you do the following things?	Total
S1	Put more clothes on if you are feeling a bit cold, before putting the heating on	n=139
S2	Close windows and doors when the heater is on	n=140
S3	Switch off lights when you are not in the room	n=141
S4	Boil the kettle with just the amount of water you are going to use	n=140
S5	When using the dishwasher or washing machine, wash only full loads, while setting the lowest water temperature possible	n=134
S6	Buy energy saving light bulbs and appliances	n=146

As Figure 4.13 shows, a majority of respondents indicated that they engage in energy-efficient behaviours. A 5-point Likert scale ranging from 1 to 5 was applied to the statement in the direction “Never” to “Always”. The mean was 3.6241 and the standard deviation from the mean was 0.06612, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents quite often engage in energy-saving behaviours.

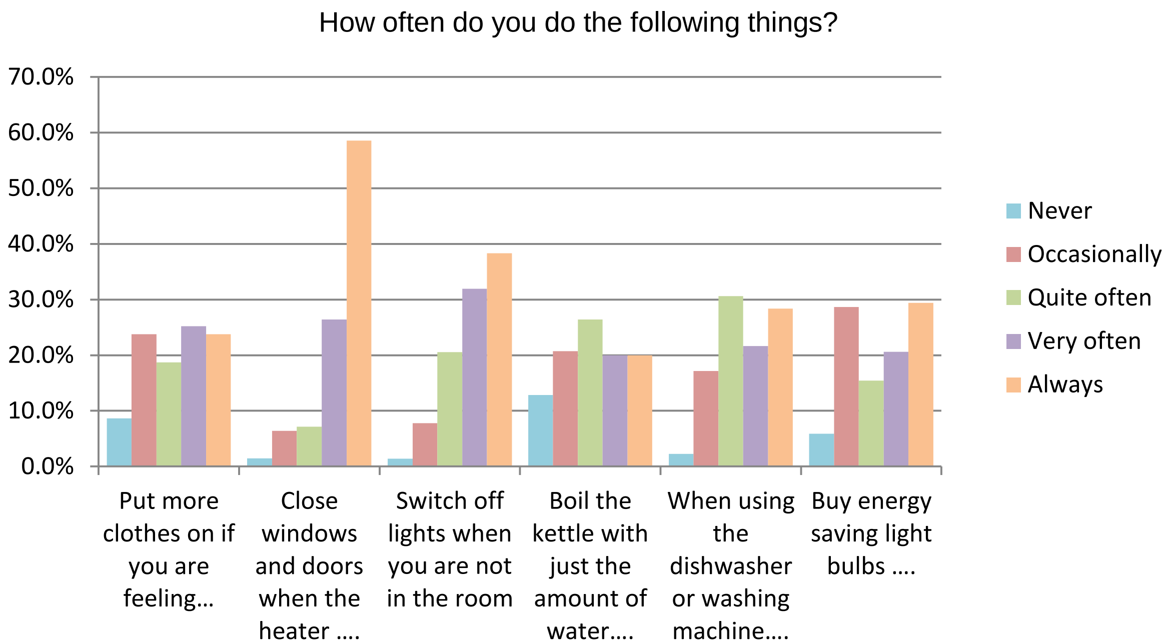

FIGURE 4.13 – Responses to energy-efficient behaviour statements

Respondents were also asked to rate the following statements in Table 4.21 to determine how often they engage in non-conserving behaviours in their day-to-day activities. Again, the 7-category Likert scale was reduced down to five by excluding the “Don’t know” and “N/A” (Not Applicable) categories.

TABLE 4.21 – Non-conserving behaviour statements

	How often do you do the following things?	Total
S7	Leave your TV or PC on standby for long periods of time	n=139
S8	Spend more time in the shower, and/or use lots of hot water for baths to keep warm	n=141
S9	Dry clothes on radiators	n=141
S10	Leave a mobile phone charger switched on at the socket when not in use	n=141

As Figure 4.14 shows, respondents also indicated that they engage in some non-conserving behaviours. A 5-point Likert scale ranging from 1 to 5 was applied to the statement in the direction “Never” to “Always”. The overall mean was 3.2242 and the standard deviation from the mean was 0.0758, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that they quite often engage in non-conserving behaviours.

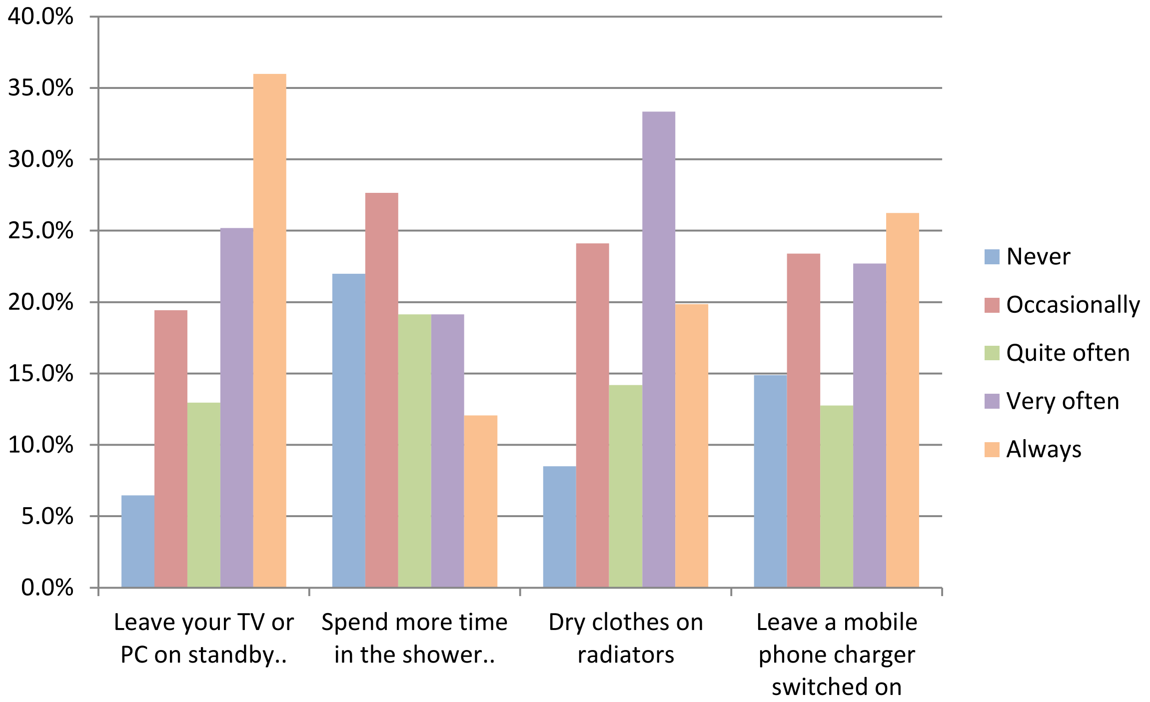

FIGURE 4.14 – Responses to non-conserving behaviour statements

Respondents were asked to indicate their level of agreement or disagreement with the statements in Table 4.22.

TABLE 4.22 – Statements on energy-saving practices

	To what extent do you agree or disagree with the following statements?	Total
S11	Energy saving practices will reduce my electricity bill	n=138
S12	Energy saving practices will reduce my comfort	n=138

As Figure 4.15 shows, 4.3% of respondents indicated disagreement with S11, 5.1% neither agree nor disagree, while 90.6% indicated agreement ranging from “Agree” to “Strongly agree”. For S12, 15.3% of respondents indicated disagreement, 14.6% neither agree nor disagree, while 70.1% indicated agreement ranging from “Agree” to “Strongly agree”.

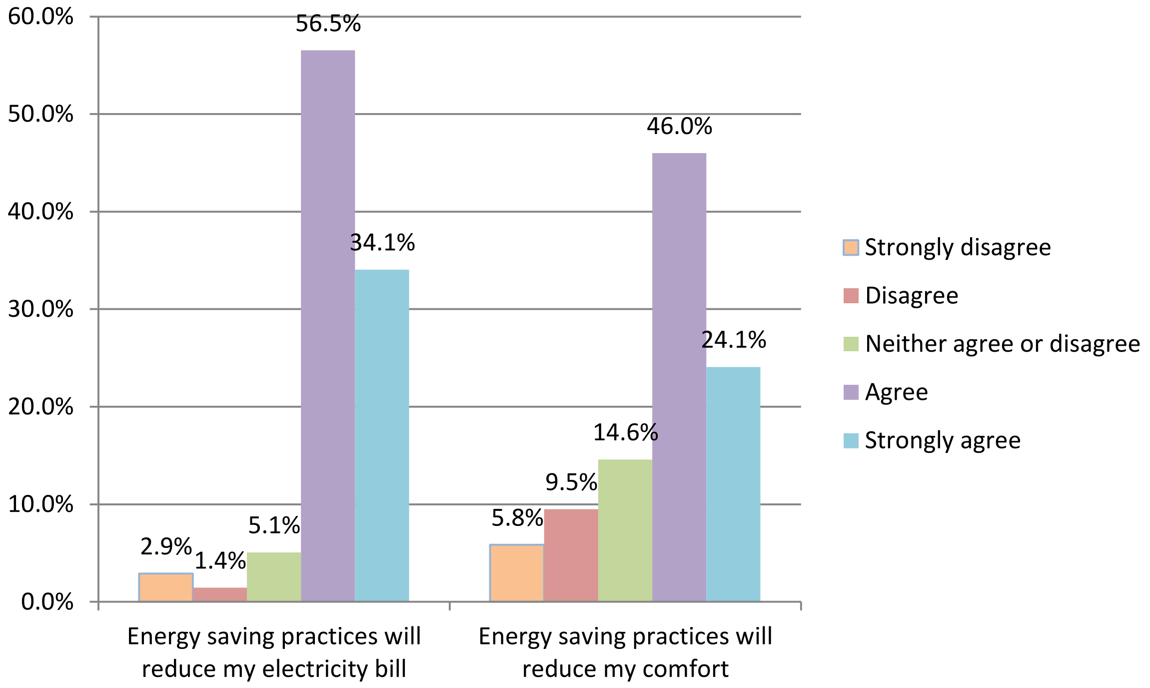

FIGURE 4.15 – Responses to energy saving practices statements

A 5-point Likert scale ranging from 1 to 5 was applied to the statement in the direction "Strongly disagree" to "Strongly agree". For S11, the mean was 4.1739 and the standard deviation from the mean was 0.1745, thus indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that they agree that energy saving practices will reduce their electricity bill. The mean for S12 was 3.7300 and the standard deviation from the mean was 0.1655, thus also indicating that 68% of the responses are close to the mean and also suggesting that on average, respondents indicated that they neither agree nor disagree that energy saving practices will reduce their comfort.

Respondents were also asked the following question:

"Do you think that an In-Home Display would encourage you to play a more active role in managing your electricity usage?"

From the data in Figure 4.16, a majority of respondents (69.8%) indicated that they think an IHD would encourage them to engage in energy saving practices, 15.8% do not think so, while 14.4% do not know.

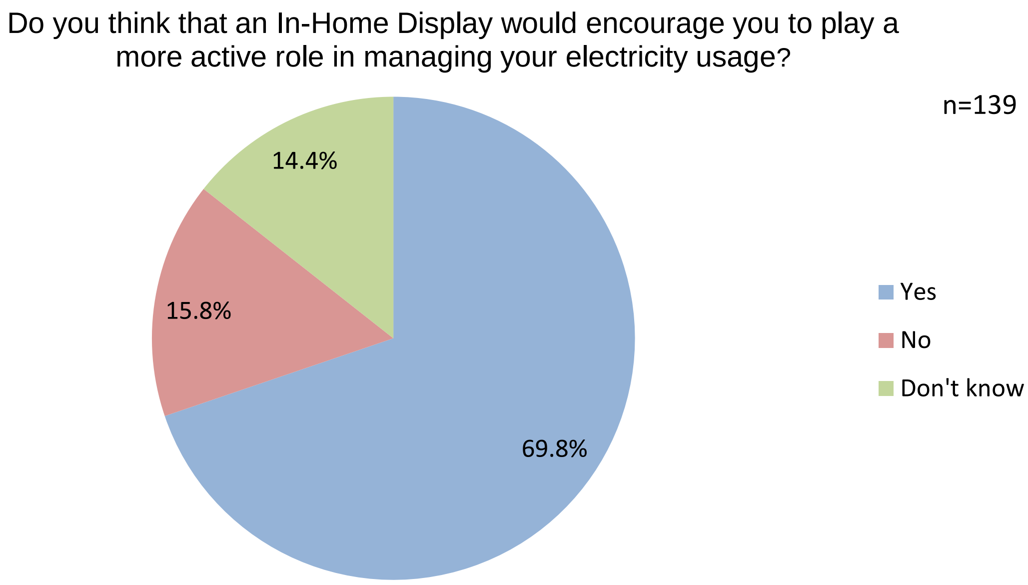

FIGURE 4.16 – Responses to change in energy use behaviour with the help of IHD

Hypothesis 6: *Age will moderate the influence of resistance to lifestyle change on potential to use IHDs to the extent that it will be stronger among older adults.*

To determine the moderating effect of age on the influence of resistance to lifestyle change on potential to use IHDs, the statement: "Do you think that an In-Home Display would encourage you to play a more active role in managing your electricity usage?" was cross-reference against age and a Chi-square test was performed to test for statistical significance. From the data in Table 4.23, it is clear that regardless of age, the majority of respondents think that an IHD would encourage them to play a more active role in managing their electricity usage.

TABLE 4.23 – "…an In-Home Display would encourage you…" by Age category

n=138

Do you think that an In-Home Display would encourage you..?	18-30	31-45	46+	Total
Yes	20	67	21	**108**
No	3	9	8	**20**
Don't know	5	3	2	**10**
Total	**28**	**79**	**31**	**138**

The Chi-square test returned a Chi-square statistic of 10.250, df (degree of freedom) of 4 and a p-value (probability of chance) of 0.0364. This result was deemed statistically significant as the p-value is less than $\alpha = 0.05$.

Statement S12 (Table 4.22, p. 74) was cross-referenced against age category and a 5-point Likert scale ranging from 1 to 5 was applied to the statement in the direction “Strongly disagree” to “Strongly agree”. Interestingly, the results of the mean and standard deviation as shown in Table 4.24 suggest that there is a correlation between statement S12 and age variable. More interestingly, this correlation appears to be quite strong with age category 18-30 and 46+. On average, respondents in age category 18-30 and 46+ agree that energy saving practices will reduce their comfort, while those in 31-45 neither agree nor disagree.

TABLE 4.24 – “Energy saving practices will reduce my comfort” by Age category

n=137

Energy saving practices will reduce my comfort	18-30	31-45	46+	Total
Strongly disagree	0	7	1	**8**
Disagree	1	12	0	**13**
Neither agree nor disagree	5	12	3	**20**
Agree	14	30	19	**63**
Strongly agree	8	17	8	**33**
Total	**28**	**78**	**31**	**137**
Mean	**4.0357**	**3.4872**	**4.065**	
SD	**0.3866**	**0.2128**	**0.3681**	

The 5-category Likert scale (Table 4.24) was reduced down to 3 by combining “Agree” and “Strongly agree” into a single category and “Disagree” and “Strongly disagree” into another. This allowed for further statistical analysis using Chi-square test.

The Chi-square test returned a Chi-square statistic of 83.586, df (degree of freedom) of 4 and a p-value (probability of chance) of 0.0000. This result was deemed statistically significant as the p-value is less than $\alpha = 0.05$. Therefore, H6 is supported and the null hypothesis (H_0) that age will not moderate the influence of resistance to lifestyle change on potential to use IHDs, such that its effect is stronger among older adults, is rejected.

4.5 Summary

The theoretical framework used for this research is an adaptation of the Unified Theory of Acceptance and Use of Technology (UTAUT2), specifically customised to best fit in the context of consumer receptivity to IHDs as described in section 3.8, Proposed Research Model, pp. 43-47 and illustrated in Figure 3.3, p. 44. The six constructs of the research model were used to design the online questionnaire, which sought to garner interesting and unbiased responses from participants.

The research findings revealed that on average, there was a low level of familiarity with IHDs among respondents, who also on average expressed slight interest in buying an IHD despite the ever-increasing energy bills. However, a majority of respondents indicated that they would use an IHD primarily to realise savings on electricity bills. This corroborates the mean calculated for responses to the question about using IHD to realise 20 percent savings on electricity bills, in which on average, respondents indicated that they would “Moderately likely” use an IHD if it could help them realise monthly savings of up to 20 percent.

Toward addressing the research question, six hypotheses developed from the customised theoretical framework employed in this study were statistically tested. Disappointingly, due to the significant underrepresentation of some categories in the bill payer and household size demographic variables, the effect of these moderators (illustrated in Figure 3.3, section 3.8, Proposed Research Model, p. 44) could not be tested in this study. However, despite the aforementioned underrepresentation, the survey revealed some very interesting and surprising data that provide new insights into the degree to which demographic variables moderate the effect of the factors that influence consumer receptivity to IHDs and potential to use IHDs.

The next Chapter, will therefore, move on to discuss these new and interesting findings that have arisen from this study. In Chapter 5, the findings will be linked to the review of literature, action steps in response to the findings will be explored and the limitations and future directions for this research will be highlighted.

5 Conclusions and Future Work

5.1 Introduction

The main objective of this research is to determine the factors that influence consumer receptivity to in-home displays (IHD). Toward addressing the research question (see section 1.2, Research Question, p. 3), a new question arose (sub-question), which sought to determine the degree to which demographic variables moderate the effect of the constructs (described in section 3.8, Proposed Research Model, pp. 43-47) on consumer receptivity to IHDs and potential to use IHDs. This chapter highlights the findings of the quantitative study and briefly discusses how these findings answered the research question, linking them to the reviewed literature. It summarises the key points from this research, outlines recommendations based on the research findings and the reviewed literature, acknowledges the limitations of this research and suggests directions for future research in this area.

5.2 Answering the Research Question

Following an extensive review of the literature, a research model (section 3.8, Proposed Research Model, pp. 43-47) customised from UTAUT2 (Venkatesh et al., 2012) to best fit in the context of consumer receptivity to IHDs was proposed to address the research question and sub-question (see section 1.2, Research Question, p. 3). This model is comprised of two new constructs namely aesthetics design and resistance to lifestyle change, in addition to four constructs from UTAUT2: performance expectancy, effort expectancy, price value and facilitating conditions. Demographic variables: household size, bill payer, familiarity and age were hypothesised to moderate the effects of the constructs on consumer receptivity to IHDs and potential to use IHDs. As a result, the following hypotheses were developed from the proposed research model and tested:

H1: Age will moderate the influence of performance expectancy on consumer receptivity to IHDs to the extent that it will be stronger among younger and older adults.

H2: Age and familiarity will moderate the influence of effort expectancy on consumer receptivity to IHDs to the extent that it will be stronger among older people, particularly those who are less familiar with IHDs.

H3: Age will moderate the influence of aesthetic design on consumer receptivity to IHDs to the extent that it will be stronger among young adults.

H4: Age will moderate the influence of price value on consumer receptivity to IHDs to the extent that it will be stronger among older adults.

H5: Age and familiarity will moderate the influence of facilitating conditions on potential to use IHDs to the extent that it will be stronger among younger and older people who are more familiar with IHDs.

H6: Age will moderate the influence of resistance to lifestyle change on potential to use IHDs to the extent that it will be stronger among older adults.

However, of the hypotheses listed above, *H4* and *H5* were not proven.

This study unveiled evidence (see section 4.4.1, Performance Expectancy, pp. 56-59) showing that performance expectancy influences consumer receptivity to IHDs. This finding corroborates with the findings of other studies on technology adoption by Davis (1992), Venkatesh and Davis (2000), Taylor and Todd (2001) and Venkatesh (2003). The effect of performance expectancy on consumer receptivity to IHDs was statistically proven to be moderated by age, such that it was stronger among the youngest (18–30) and oldest (46+) age categories. The results, not surprisingly, revealed that a majority (75%) of respondents would primarily use an IHD to realise financial savings rather than solve the climate change problem.

The results, as presented in section 4.4.2, Effort Expectancy (pp. 59-63) indicate that effort expectancy influences consumer receptivity to IHDs. This supports earlier findings of studies on technology adoption by Venkatesh et al. (2003), Ghalandari (2012), and Raman and Don (2013), which suggest that effort expectancy has a positive effect on consumers' acceptance and use of technology. Statistical evidence showed that age and familiarity moderated the effect of effort expectancy on consumer receptivity to IHDs such that it was stronger among participants in the oldest age group (46+) who are less familiar with IHDs, thus supporting findings of studies on ageing and implicit learning by Smyth (2009), which suggest that perceived effort of learning increases with age; and findings of studies on the dimensions of consumer knowledge by Alba and Hutchinson (1987), which suggest that familiarity results in lower cognitive efforts required to accomplish tasks and improves a person's ability to analyse information.

The results presented in section 4.4.3, Aesthetics Design (pp. 63-67) indicate that aesthetics design will influence a person's receptivity to IHDs. The results therefore support claims by Lidwell et al. (2010) that people are more likely to develop positive attitudes toward a technology with aesthetic design than a similar technology with un-aesthetic design. Age was statistically proven to moderate the influence of aesthetics design on consumer receptivity to IHDs to the extent that it was stronger among participants in the youngest age group (18–30), thus supporting findings of studies by Reinecke et al. (2013), which suggest that young people show more interest in aesthetics design than old people.

Statistical evidence presented in section 4.4.6, Resistance to Lifestyle Change (pp. 72-77) indicate that resistance to lifestyle change influences potential to use IHDs. A majority of respondents indicated that they quite often engage in energy-saving and non-conserving behaviours, which may suggest that participants quite often display “locked-in” practices in their daily energy consumption behaviour. This finding corroborates concerns that social norms tend to lock consumers into consumption patterns akin to non-energy efficient lifestyles (Shove, 2003; EEA, 2013). Further statistical tests revealed that age moderates the influence of resistance to lifestyle change on potential to use IHDs to such an extent that it was stronger among older people. This supports the argument that: through social practices, people adopt energy consumption practices, which become habitual and routine as they age (Shove, 2003).

Preliminary results (see section 4.4.4, Price Value, pp. 67-69 and section 4.4.5, Facilitating Conditions, pp. 69-71) suggest that price value and facilitating conditions influence consumer receptivity to IHDs. Disappointingly, the moderating effect of demographic variables on the influence of these two constructs on consumer receptivity to IHDs could not be verified in this study as the Chi-square test showed that the results were statistically insignificant.

5.3 Interesting New Findings

As explained earlier in the previous section, the results indicate that age moderated the influence of resistance to lifestyle change on potential to use IHDs such that its effect was strongest among participants in the oldest (46+) age category (see Table 4.24, section 4.4.6, Resistance to Lifestyle Change, p. 77). The reviewed literature (Shove, 2003; EEA, 2013) suggest that through social practices, people adopt energy consumption practices that become habitual and routine as they age; this may explain why the influence of resistance to lifestyle change on potential to use IHDs was strongest among participants in the oldest age category. Interestingly, new finding also suggest that resistance to lifestyle change has a strong influence on young people’s potential to use IHDs as evident in the survey results, which revealed that the influence of resistance to lifestyle change on potential to use IHDs was almost equally strong among participants in the youngest (18–30) age category (see Table 4.24, section 4.4.6, Resistance to Lifestyle Change, p. 77).

This new evidence corroborates Shove (2003) who argues that studies on energy efficiency should focus on social norms instead of individual consumption, as they tend to lock consumers into consumption patterns akin to non-energy efficient lifestyles (EEA, 2013). Therefore, this new finding may suggest that social practices akin to non-conserving behaviours in early childhood development will impact potential to use IHDs. This new finding supports the need for age appropriate energy efficiency programmes to be introduced to schools where children can learn how to be energy efficient at a young age.

5.4 Key Points from the Research

This study provides substantial evidence (see section 4.4.3, Aesthetics Design, pp. 63-67) to suggest that there is a low level of awareness of IHDs in spite of the growing number of new IHD products and companies that have emerged, and the high energy costs. The findings support the need for governments to support utility providers in offering free in-home displays to domestic consumers as part of ongoing energy efficiency initiatives that involve the roll-out of smart meters. This requirement was informed by the reviewed literature, which suggests that many utility providers see business retention or new business opportunities as the driver for engaging with customers in energy savings programmes and initiatives; not surprisingly, two utility providers in Ireland refused to grant authorisation for their customers to be surveyed as part of this research. As utility providers play a crucial role in ensuring all consumers have some level of information that enables them to understand their energy usage, they are key to helping domestic consumers manage and reduce their energy consumption. Furthermore, consumers tend to trust energy conservation advice from their utility providers rather than third-parties, such as device manufacturers, and would therefore be more willing to accept and use an IHD if offered one by their utility providers.

The study also provides invaluable insights into how resistance to lifestyle change influences receptivity to IHDs by gauging specific behaviours. The evidence (see section 4.4.6, Resistance to Lifestyle Change, pp. 72-77) presented is quantitative, statistically proven to be significant, and are therefore not based on claims. The most striking finding to emerge from this study is that a majority of participants who indicated that they engage in energy-saving behaviours also indicated that they engage in non-conserving behaviours, which may suggest that these participants value their comfort; so they are unlikely to compromise their quality of life to save the environment or cut energy costs. This poses a great, long-term challenge for governments, utility providers, and manufacturers of energy feedback devices with no easy and immediate answer.

The study examined the quality of feedback information provided by IHDs. The findings (see Table 4.15, section 4.4.4, Price Value, p. 67) indicate that most participants would prefer IHDs that provide appliance-level feedback as this will enable them to quickly and easily identify the energy guzzlers in their homes. Currently, entry-level IHDs provide whole house energy consumption and cost, which is much the same as replacing the traditional monthly energy bill with a daily bill and yet it still lacks information, which is needed to be more energy efficient. Although consumers are still able to identify energy guzzlers with entry-level IHDs, by turning off all appliances and then turning them on one at a time, this approach requires considerable time and effort depending on how many appliances are present in the home. Almost equally preferred are IHDs that provide alerts for appliances left switched on. These findings suggest the need for improvements in the feedback quality of entry-level IHDs, which ideally should provide consumers with both appliance-level feedback and alerts for appliances left switched on or consuming the most energy. These improvements could increase the usefulness of IHDs thereby adding value.

This study delved into the intricate relationship between water and energy, as hot water use is also a sizable use of energy. The findings (see Figure 4.14, section 4.4.6, Resistance to Lifestyle Change, p. 74) indicate that most participants engage in non-conserving behaviours that are water related, particularly, spending more time in the shower. Interestingly, since water and energy are inextricably linked, less hot water use equates to a sizable reduction in energy use, which translates into lower water heating bills; hence domestic water conservation will help tackle the climate change problem. More interestingly, with the planned introduction of water charges in Ireland in 2015, people will now have an important incentive to find ways of reducing their water use or the amount of water wasted on a daily basis, particularly, power showers that consume a lot of water and electricity.

Overall, the findings suggest that the six constructs (described in section 3.8, Proposed Research Model, pp. 43-47) listed below influence consumer receptivity to IHDs, with resistance to lifestyle change arguably being the most problematic.

1. Performance Expectancy.

2. Effort Expectancy.

3. Aesthetics Design.

4. Price Value.

5. Facilitating Conditions.

6. Resistance to Lifestyle Change.

The findings broadly suggest that more work needs to be done in promoting the uptake of IHDs. Although the study indicates that an overwhelming majority of participants would use an IHD primarily for financial gain and not climate change, regardless of what the primary reason is, one thing is certain: consumers must change their energy use behaviour.

5.5 Recommendations

Based on the findings from the survey and the reviewed literature, this study puts forth the following recommendations:

5.5.1 Government Backed Schemes and Initiatives that Promote the Uptake of IHDs

Government could embark on energy efficiency initiatives that require utility providers to offer free IHDs to Irish households. This should be complemented with financial incentive schemes aimed at enticing the public, utility providers and other stakeholders in the energy market into investing in IHDs, thereby surmounting market barriers. Financial incentives could be offered in the form of tax incentives targeted at consumers who purchase IHDs, manufacturers of IHDs, distributors and retail outlets for IHDs. Mass media campaigns could be used to ensure that Irish energy consumers and other stakeholders are aware of the full range of financing incentives provided. Government could also embark on several initiatives to incentivise utility providers to engage with consumers to reshape their energy use behaviour following interaction with feedback from IHDs. This could also be in the form of tax incentives for utility providers that offer lower tariff rates or discounts to consumers based on agreed household energy-saving targets, thus ensuring the continuous use of IHDs.

5.5.2 Improvements in the Quality of IHD Feedback

Entry level IHDs could be upgraded to provide appliance-level feedback and alerts for energy guzzling appliances. Appliance specific breakdowns will offer greater levels of savings, as consumers will be able to quickly and easily identify which appliance is consuming the most energy. Basic IHDs could include alert features for whole-house and appliance-level energy consumption with the option for user-defined metrics. This will make them more engaging, acting as knowledge improvement tools for energy consumption and instantaneous reminders for energy waste. As a result, consumers will see value for money as being more important than just the price of IHDs.

5.5.3 Education Programmes for Energy Conservation

Policymakers could partner with researchers and other stakeholders in energy efficiency to implement a structured energy efficiency programme aimed at educating citizens on the broad benefits of energy efficiency, which could include raising awareness of cost-effective energy efficiency technologies and their capabilities. Through such a programme, consumers could learn how water usage impacts energy consumption and vice versa. They could also learn how to efficiently respond to feedback and maximise benefits without compromising their quality of life. For example, with the high water consumption rate in Ireland in the excess of 141 litres per person per day, which is well above the European average, energy efficiency programmes could be used to educate children and adults alike on how to save water and energy using new innovative products, such as shower timers, that limit shower times. This could be included in age appropriate energy efficiency programmes, such as the Green-schools programme, where children learn how to be energy efficient at a young age.

5.6 Contribution to Research Field

This study provides a potential framework for researchers to continue advancing the field by developing and testing novel hypotheses, and opening new ways to tackle the climate change problem.

The new findings discussed earlier in section 5.3, Interesting New Findings (pp. 81-82), will add to the existing body of knowledge with respect to the adoption of in-home displays.

5.7 Generalisation of Findings

This study is of interest to the public and stakeholders in the energy efficiency marketplace. However, the findings have limited generalisations for the following four reasons:

1. Some age categories (18-30, 31-45 and 65+) were disproportionately represented.

2. A convenience sample size of 141 respondents was used for this study and is therefore not representative of the entire household population in Ireland.

3. The survey was conducted online, which limits the sample to participants who are either Internet literate or are able to get assistance in completing the survey.

4. The survey targeted specific online forums. Therefore the sample is not representative of the entire household population in Ireland.

A combination of survey distribution methods, such as email, hand-delivered and social media, could have been employed to provide more channels to increase the reach of the questionnaire. The hand-delivered distribution method could have been a more effective way to invite participants aged 65+. Participants aged between 18 and 30, could have been better targeted via social media, such as Facebook and Twitter. However, due to financial and time constraints, as well as ethical concerns, it was not possible to use social media and hand-delivered distribution methods.

5.8 Limitations of the Research

This research facilitated the development of a flexible model (section 3.8, Proposed Research Model, pp. 43-47) customised to best fit in the context of consumer receptivity to IHDs. Although the model was immensely useful for testing the hypotheses and ultimately answering the research question and sub-question, its full potential could not be explored due to the disproportionate representation of some demographic categories, which resulted in the exclusion of two demographic variables, namely bill payer and household size from the hypothesis testing.

Due to time and financial constraints, a convenience sample of 141 respondents was used to determine the factors that influence consumer receptivity to IHDs thus resulting in limited generalisations from the results in this study. Furthermore, considering the fact that climate change is an inherently global issue, it would have been ideal if the participants were widely geographically dispersed rather than restricting the study to households in Ireland. Future research may consider a geographically dispersed study population for cross-cultural comparisons.

Despite initial efforts made to ensure all age categories were well represented in this study, the 18-30, 45-64 and 65+ age categories were under represented. However, re-opening the survey for another two weeks and subsequently combining the 45-64 and 65+ age categories into one category (46+) did help increase the numbers. It would have been beneficial and perhaps interesting to compare results of the 65+ age category in the data analysis.

5.9 Future Research Opportunities

The proposed model for this study is an adaptation of UTAUT2 (Venkatesh et al., 2012) comprising of two new constructs in addition to four constructs from UTAUT2. The model is flexible, and could be used for testing new hypotheses by including other constructs and their predicted moderators. Future work in this area could determine the moderating effect of bill payer and household size on the influence of the constructs on receptivity to IHDs as this could not be determined in this study due to the poor representation of some categories in the variables (bill payer and household size). Future research could also explore the full potential of this model in order to identify other constructs that may influence consumer receptivity to IHDs including their moderators.

Future research could focus on gaining in-depth understanding of why consumers engage in both energy-saving and non-conserving behaviours and the reasons that govern these behaviours. Although this study demonstrates that a majority of participants engage in both behaviours, it is quantitative and therefore does not establish if the co-existence of these behaviours is as a result of social norms that are stiffly resistant to change. Besides, this is beyond the scope of the study, which sets out to determine the factors that influence consumer receptivity to IHDs and their moderators. A Qualitative study could be used to gain deeper insights into consumer behaviours and habits. This is an interesting and important area of future research as its findings could be useful to policymakers in setting energy efficiency targets.

Future research could examine and compare the effectiveness of feedback and alerts from IHDs, as findings of this study indicate that a majority of participants would prefer IHDs that provide appliance-level feedback; this was closely followed by the preference for alerts. This may suggest that consumers may have two perceptions of the functions of IHDs that seem to relate to arguments by Carroll et al. (2013) that IHDs act as knowledge improvement tools (feedback), and Faruqui et al. (2010) that IHDs may serve as energy saving reminders (alerts). Findings of future research in this area would be of interest to IHD manufacturers, as this will help in identifying new areas of improvement.

The reviewed literature suggest that feedback-induced energy savings can be significant (Darby, 2006; Ehrhardt-Martinez et al., 2010; Faruqui et al., 2010). As well as proving feedback on energy consumption, home energy management systems (HEMS) provide an automatic interface for consumers to manage, control and monitor their energy consumption. Most HEMS function in the background performing programmed tasks, such as switching on/off appliances for a specific duration (user defined) in the day. HEMs allow users to control their energy use through programmed tasks; thus unlike IHDs, HEMS are less dependent on behavioural change. As previously suggested in studies by Van Dam et al. (2010), future research could examine and compare the effectiveness of these technologies as this could identify areas of improvements for IHDs, such as including a new functionality that will allow consumers to automate basic tasks.

5.10 Summary

This research demonstrated that the following six constructs influence consumer receptivity to IHDs:

1. Performance Expectancy.
2. Effort Expectancy.
3. Aesthetics Design.
4. Price Value.
5. Facilitating Conditions.
6. Resistance to Lifestyle Change.

It provides statistical evidence that the effect of four of the constructs, namely performance expectancy, effort expectancy, aesthetics design and resistance to lifestyle change, are moderated by familiarity and/or age. Based on the findings of this study and the reviewed literature, it can be argued that resistance to lifestyle change is the most problematic; this poses a great challenge to energy efficiency measures targeting behaviour change. Therefore, the immediate focus of most energy efficiency initiatives/programmes should be on finding ways to encourage consumers to change their energy use behaviour following their interaction with feedback from IHDs as there is a long way to go and much work to do in tackling the climate change problem. In-home display is only a part of the solution; it is ultimately the consumers’ responsibility to react to the feedback provided by IHDs.

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Appendices

Appendix 1 – Ethics Application

School of Computer Science and Statistics
Research Ethical Application Form

Part A

Project Title: In-Home Displays: Factors Influencing Consumer Receptivity

Name of Lead Researcher (student in case of project work): Frederick Ikoli

Name of Supervisor: Paula Roberts

TCD E-mail: Ikolif@tcd.ie Contact Tel No.: 0876608409

Course Name and Code (if applicable): M.Sc. Management of Information Systems

Estimated start date of survey/research: 24th of March 2014

I confirm that I will (where relevant):

- Familiarize myself with the Data Protection Act and the College Good Research Practice guidelines http://www.tcd.ie/info_compliance/dp/legislation.php;
- Tell participants that any recordings, e.g. audio/video/photographs, will not be identifiable unless prior written permission has been given. I will obtain permission for specific reuse (in papers, talks, etc.)
- Provide participants with an information sheet (or web-page for web-based experiments) that describes the main procedures (a copy of the information sheet must be included with this application)
- Obtain informed consent for participation (a copy of the informed consent form must be included with this application)
- Should the research be observational, ask participants for their consent to be observed
- Tell participants that their participation is voluntary
- Tell participants that they may withdraw at any time and for any reason without penalty
- Give participants the option of omitting questions they do not wish to answer if a questionnaire is used
- Tell participants that their data will be treated with full confidentiality and that, if published, it will not be identified as theirs
- On request, debrief participants at the end of their participation (i.e. give them a brief explanation of the study)
- Verify that participants are 18 years or older and competent to supply consent.
- If the study involves participants viewing video displays then I will verify that they understand that if they or anyone in their family has a history of epilepsy then the participant is proceeding at their own risk
- Declare any potential conflict of interest to participants.
- Inform participants that in the extremely unlikely event that illicit activity is reported to me during the study I will be obliged to report it to appropriate authorities.
- Act in accordance with the information provided (i.e. if I tell participants I will not do something, then I will not do it).

Signed: .... Date: 10/03/2014
Lead Researcher/student in case of project work

Part B

Please answer the following questions.		***Yes/No***
Has this research application or any application of a similar nature connected to this research project been refused ethical approval by another review committee of the College (or at the institutions of any collaborators)?		NO
Will your project involve photographing participants or electronic audio or video recordings?		NO
Will your project deliberately involve misleading participants in any way?		NO
Is there a risk of participants experiencing either physical or psychological distress or discomfort? If yes, give details on a separate sheet and state what you will tell them to do if they should experience any such problems (e.g. who they can contact for help).		NO
Does your study involve any of the following?	Children (under 18 years of age)	NO
	People with intellectual or communication difficulties	NO
	Patients	N0

SCSS Research Ethics Application Form September 2011

Appendix 2 – Information Page for Participants

BACKGROUND OF RESEARCH:

This research relates to home energy management using in-home Displays (IHD) also known as Home Energy Monitors (HEM). An online survey will be conducted on residential consumers in order to identify the factors that influence their receptivity to this energy-saving technology. By participating in this survey, you will contribute to our study of the factors that influence consumer receptivity to in-Home Displays.

THE SURVEY PROCESS:

The following points should be noted about the survey:

• Your participation is voluntary and anonymous;

• The survey will take you approximately 10 minutes to complete and each question is optional;

• You have the right to withdraw from the interview at any time during the process without penalty;

• You may refuse to answer a question without penalty.

OTHER INFORMATION:

• This information is being gathered for the completion of a dissertation as part of the M.Sc. in Management of Information Systems.

• I have no conflict of interest with regard to the research topic and with any of the participants either individually or at an organisational level.

• I am required by TCD to inform you that, in the extremely unlikely event that illicit activity is reported I will be obliged to report it to appropriate authorities.

• Please do not name third-parties in any open text field of the questionnaire. Any such replies will be anonymised.

Appendix 3 – Informed Consent Form

RESEARCHER: Frederick Ikoli

CONTACT DETAILS: ikolif@tcd.ie

BACKGROUND OF RESEARCH

The rising cost of energy (electricity and gas), as well as the planned re-introduction of domestic water charges for Irish households, will force many households to seek ways to save money on energy and water bills. This survey relates to the use of In-Home Displays (also known as Home Energy Monitors) to save money on electricity bills by cutting energy use.

PROCEDURES OF THIS STUDY

Participation in this survey is voluntary and anonymous. All survey participants must be 18 years of age or older. The survey will take you approximately 10 minutes to complete and each question is optional. If you feel uncomfortable with a question, you can skip that question or withdraw from the study altogether; however the researcher would be grateful if all questions were responded to. If you decide to quit by clicking the "Exit This Survey" button at any time before you have finished the questionnaire, your answers will NOT be recorded.

PUBLICATION

At the end of the survey, individual results will be aggregated anonymously and research reported on aggregate results. The results will be used solely for a dissertation as part of the completion of a M.Sc. in Management of Information Systems course at Trinity College Dublin (TCD).

CONFIDENTIALITY

Your responses will be kept completely confidential.

If you have any questions or concerns or if you have any difficulties accessing this survey, you may contact me at: ikolif@tcd.ie.

Should you have any questions or concerns regarding possible ethical issues in this research, you may contact the ethics committee of the SCSS by email: research-ethics@scss.tcd.ie.

DECLARATION:

• I am 18 years or older and am competent to provide consent.

• I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.

• I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.

• I understand that if I make illicit activities known, these will be reported to appropriate authorities.

• I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.

• I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.

• I understand that my participation is fully anonymous and that no personal details about me will be recorded.

• Since this research involves viewing materials via a computer monitor I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.

By submitting this form you are indicating that you have read the description of the study, are over the age of 18, and that you agree to the terms as described.

Thank you in advance for your participation!

Frederick Ikoli

Do you agree to the consent information listed on this form?

○ Yes

○ No

Appendix 4 – Questionnaire

<b>In-Home

INFORMATION PAGE FOR SURVEY PARTICIPANTS

TRINITY COLLEGE DUBLIN
INFORMATION PAGE FOR SURVEY PARTICIPANTS

BACKGROUND OF RESEARCH:

This research relates to home energy management using In-home Displays (IHD) also known as Home Energy Monitors (HEM). An online survey will be conducted on residential consumers in order to identify the factors that influence their receptivity to this energy-saving technology. By participating in this survey, you will contribute to our study of the factors that influence consumer receptivity to In-Home Displays.

THE SURVEY PROCESS:

The following points should be noted about the survey:

• Your participation is voluntary and anonymous;

• The survey will take you approximately 10 minutes to complete and each question is optional;

• You have the right to withdraw from the interview at any time during the process without penalty;

• You may refuse to answer a question without penalty.

OTHER INFORMATION:

• This information is being gathered for the completion of a dissertation as part of the M.Sc. in Management of Information Systems.

• I have no conflict of interest with regard to the research topic and with any of the participants either individually or at an organisational level.

• I am required by TCD to inform you that, in the extremely unlikely event that illicit activity is reported I will be obliged to report it to appropriate authorities.

• Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised.

<b>In-Home

INFORMED CONSENT FORM

TRINITY COLLEGE DUBLIN
INFORMED CONSENT FORM

RESEARCHER: Frederick Ikoli

CONTACT DETAILS: ikolif@tcd.ie

BACKGROUND OF RESEARCH
The rising cost of energy (electricity and gas) as well as the planned re-introduction of domestic water charges for Irish households will force many households to seek ways to save money on energy and water bills. This survey relates to the use of In-Home Displays (also known as Home Energy Monitors) to save money on electricity bills by cutting energy use.

PROCEDURES OF THIS STUDY
Participation in this survey is voluntary and anonymous. All survey participants must be 18 years of age or older. The survey will take you approximately 10 minutes to complete and each question is optional. If you feel uncomfortable with a question, you can skip that question or withdraw from the study altogether; however the researcher would be grateful if all questions were responded to. If you decide to quit by clicking the "Exit This Survey" button at any time before you have finished the questionnaire, your answers will NOT be recorded.

PUBLICATION
At the end of the survey, individual results will be aggregated anonymously and research reported on aggregate results. The results will be used solely for a dissertation as part of the completion of a M.Sc. in Management of Information Systems course at Trinity College Dublin (TCD).

CONFIDENTIALITY
Your responses will be kept completely confidential.

If you have any questions or concerns or if you have any difficulties accessing this survey, you may contact me at: ikolif@tcd.ie.

Should you have any questions or concerns regarding possible ethical issues in this research, you may contact the ethics committee of the SCSS by email: research-ethics@scss.tcd.ie.

DECLARATION:
• I am 18 years or older and am competent to provide consent.

• I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.

• I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.

• I understand that if I make illicit activities known, these will be reported to appropriate authorities.

• I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.

<b>In-Home

• I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.

• I understand that my participation is fully anonymous and that no personal details about me will be recorded.

• Since this research involves viewing materials via a computer monitor I understand that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.

By submitting this form you are indicating that you have read the description of the study, are over the age of 18, and that you agree to the terms as described.

Thank you in advance for your participation!

Frederick Ikoli

Do you agree to the consent information listed on this form?

○ Yes

○ No

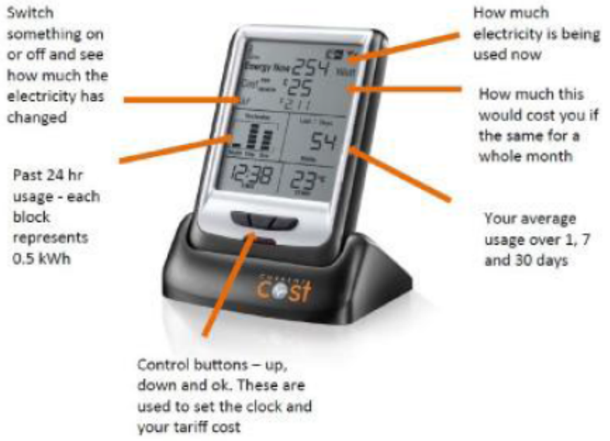
Page 3

<b>In-Home

Description of an In-Home Display

Please read the following before completing this questionnaire.

Image of an In-Home Display



In-Home Displays (also known as Home Energy Monitors) show how much electricity, water or gas is being used in the home at any one time and how much it will cost. They can help to reduce energy (electricity and gas) and water consumption and also help people at home to identify which appliances or devices consume the most electricity. By providing up to the second information on electricity usage and cost, households can make well informed decisions that can save them up to 20 per cent a month on their electricity bills.

Some features of In-Home Displays include the following:

- They are easy to install and uninstall
- They are easy to use
- They are easy to read
- They are portable, wireless and can be placed anywhere in the home
- They provide up to the second information on the amount of electricity, gas or water being used and how much it cost.
- They provide daily, weekly or monthly usage data and cost
- They keep track of how much energy or money is being saved.
- Alarm to notify high energy use
- Display time and date information

<b>In-Home

How familiar are you with In-Home Displays?

Not at all familiar	Slightly familiar	Moderately familiar	Very familiar	Extremely familiar
◯	◯	◯	◯	◯

How interested would you be in buying an In-Home Display?

Not interested	Slightly interested	Moderately interested	Very interested	Extremely interested
◯	◯	◯	◯	◯

How much would you be willing to pay for an In-home Display?

less than €40	€40 - €60	€60 - €80	€80 - €100	Over €100
◯	◯	◯	◯	◯

Assuming you decide to buy an in-home display, how will each of the following influence your choice? Please rate each statement.

	Not at all influential	Slightly influential	Moderately influential	Very influential	Extremely influential
It is easy to use	◯	◯	◯	◯	◯
It is interactive	◯	◯	◯	◯	◯
It is easy to install	◯	◯	◯	◯	◯
It is controlled via buttons, a touch screen, or additional software	◯	◯	◯	◯	◯
It can perform additional functions (e.g., weather or tips on energy savings)	◯	◯	◯	◯	◯
It has an artistic beauty or pleasing appearance (aesthetics)	◯	◯	◯	◯	◯

<b>In-Home

How likely would you be to use an In-Home Display for free?

Not at all likely	Slightly likely	Moderately likely	Very likely	Completely likely
◯	◯	◯	◯	◯

What would be your primary reason for using an In-Home Display?

◯ To save money on my electricity bill

◯ To cut energy waste

◯ To reduce my carbon emissions

Other (please specify)

How would you rate the usefulness of each of the following information displayed on an In-House Display?

	Not useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Information about whole house energy consumption and cost	◯	◯	◯	◯	◯
Information about whole house and appliance-level energy consumption and cost	◯	◯	◯	◯	◯
Historical usage for the past day, week and month	◯	◯	◯	◯	◯
Alerts me if an appliance is left on	◯	◯	◯	◯	◯

<b>In-Home

How often do you do the following things?

	Never	Occasionally	Quite often	Very often	Always	Don't know	N/A
Put more clothes on if you are feeling a bit cold, before putting the heating on							
Close windows and doors when the heater is on							
Leave your TV or PC on standby for long periods of time							
Switch off lights when you are not in the room							
Boil the kettle with just the amount of water you are going to use							
Spend more time in the shower, and/or use lots of hot water for baths to keep warm							
When using the dishwasher or washing machine, wash only full loads, while setting the lowest water temperature possible							
Dry clothes on radiators							
Buy energy saving light bulbs and appliances							
Leave a mobile phone charger switched on at the socket when not in use							

<b>In-Home

To what extent do you agree or disagree with the following statements?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Energy saving practices will reduce my electricity bill	○	○	○	○	○
Energy saving practices will reduce my comfort	○	○	○	○	○

Do you think that an in-home display would encourage you to play a more active role in managing your electricity usage?

- ○ Yes
- ○ No
- ○ Don't know

How likely would you be to use an In-Home Display if it could help you save up to 20 per cent a month on your electricity bill?

- ○ Not at all likely
- ○ Slightly likely
- ○ Moderately likely
- ○ Very likely
- ○ Completely likely

Graph

Chart

Text

<b>In-Home

The above images represent display formats of In-Home Displays. Which format do you prefer?

- ◯ Graph
- ◯ Chart
- ◯ Text

What would be your preferred display medium?

- ◯ A display that sat on your counter or wall
- ◯ A web portal you could log into
- ◯ A smart phone application
- ◯ No preference

Other (please specify)

How much responsibility do you have for paying electricity bill for your household? (Select one.)

- ◯ None of the responsibility
- ◯ Some of the responsibility
- ◯ Share responsibility equally with other household members (no one in your household has more responsibility for paying bills than you do)
- ◯ Most of the responsibility
- ◯ All of the responsibility

<b>In-Home

Dermographics

Which category below includes your age?

- ◯ 18-30
- ◯ 31-45
- ◯ 46-64
- ◯ 65 or older

How many people currently live in your household?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 or more