Ubiquitous Computing in the Domestic Space for Environmental Sustainability

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Abstract

It is a commonly held view that technology is a tool aimed at the workplace, designed to promote efficiency and increase revenue streams. While this is true, computing is one of the most diverse tools humans have created to improve the standards of living. New emerging technologies force the evolution of radical computing paradigms, in an industry once solely directed at business. In this thesis, quantitative distinctions of the main computing, social and spacial models are made and used to substantiate criticisms of existing systems. This thesis addresses a cultural and socialistic change in the way technology is embedded into human life. Through applied research, it establishes the importance of ubiquitous systems and social change for the support of environmental sustainability.

This thesis highlights that the means to change human culture surrounding energy waste is present but, due to constricted views on how these systems should behave, are not implemented successfully. The research conducted shows that the domestic space needs to be a primary target for government action, if certain carbon emission targets are to be met. It validates the idea that new methodologies in domestic spaces have to be embraced to influence a behavioural change of end-point consumers en masse. This thesis further explores the current solutions that are available to this audience and evaluates how the lack of a solid framework hinders the development of these ubiquitous systems. The subsequent conclusions that are made, suggest possible solutions that address the criticisms from this thesis and the problems surrounding ubiquitous computing in the domestic environment. It is concluded that the relationship and perception an inhabitant has of their domestic space needs to change, through the mediation of ubiquitous systems.

Introduction and Overview

As the population expands, cities become bigger and local governments struggle to keep up with the demand for housing. “The world is getting smaller and flatter” (Hernandez, 2005). Social media and other computing paradigms enable people to establish and maintain connectivity to each other, in real-time regardless of location. This breakthrough in technology, stemming from the internet, transgresses the concept of space and time to bring people together. The side affect of a smaller and flatter world is climate change. As more aspects of human life are uploaded and digitised, the systems and infrastructure needed to cope with the growth of data comes at a cost. This cost is energy, a natural resource. The most notable and shocking fact facing the UK is the shortage of energy. Analysts predict that by 2015 the country will not be able to generate reliable base load power to meet energy demands (The Economist, 2009). Even more alarmingly is the reality that there is no way to obtain the extra energy needed.

Natural resources are rapidly decreasing and other solutions such as nuclear power stations and renewable sources cannot solve the shortages in the time frame needed. With the scarcity of these resources depleting, how is energy wastage still the largest contributor to greenhouse gas emissions? *“Britons are the worst energy wasters in Europe with bad habits which could cost £11bn by 2010” (BBC, 2006).* Further studies indicate that the energy consumed in UK homes accounts for over 25 percent of all UK emissions of carbon dioxide (DirectGov, n.d). The problem is not just apparent in the UK however, an analysis of energy wasted in the United States economy also finds that over 56 percent of all energy generated is wasted due to inefficiencies (The New York Times, 2008). These statistics substantiate the claim that this is a recurring problem affecting many nations. The larger problem can be dramatically softened by targeting the homes and promoting small and collective behavioural changes. Solutions that exist now are being rolled out by the government in collaborations with the countries leading businesses and utility companies. The ubiquitous computing paradigm has a huge potential to combat the energy wasting behaviour of homeowner’s, by integrating smart systems into the home and subsequently into the environment's ecosystem.

The transformation that happens in a person when at home is notably different from the workplace. A completely different culture exists within the secure walls of a family's home and as such computing systems that attempt to influence behavioural changes need to become embedded and accepted into this culture. Social spatial models can help define the characteristics of these cultures and identify channels in which to communicate with people.

This paper highlights a gap that current ubiquitous systems fail to address on a human-centric level. The home is a completely different environment to the workplace and people, whilst at home, have different ideological values to those at work. The distinction between the two is often disregarded when designing solutions. This paper highlights that there is a way to embrace this culturally diverse space and apply ubiquitous computing to aid environmental sustainability.

In this paper cultural and socialistic models are analysed and evaluated against the design of current ubiquitous systems aimed at the domestic environment. The relationship between spatial ecologies of the home and the social, cultural and behavioural models of the inhabitants are explored; in an attempt to critique the 'smart' solutions government bodies are investing so much time and effort into. Are solutions designed primarily to increase revenue, effective at addressing the need for greener behavioural change? Can ubiquitous systems in the domestic environment support these changes? This paper attempts to answer these questions providing critical analysis where possible.

In chapter 1 the author investigates the core technologies and issues surrounding the interaction between human and machine. It specifically addresses issues relating to climate change and the collective impact end-point consumers have on energy consumption. This chapter also highlights some of the current developments that are used in industry to address the energy issues facing the population and the methodological approaches adopted. As changes, especially those that are technology related, are incubated in business before becoming commercially available, a business view on recent developments is used to contextualise the direction of commercial technology.

In chapter 2 the author will draw comparisons between the ubiquitous computing paradigm and domestic spatial models - anthropological, cultural, social and behavioural. From these comparisons, evaluations can be made to further suggest how to interact with the target audience (the inhabitants). By establishing a correlation between domestic communication channels and those adopted in ubiquitous systems, critiques can be made to evaluate how well current solutions can perform in the domestic environment.

Chapter 3 evaluates in greater detail the smart systems that are available to consumers and the recent developments for reducing energy wasting habits. It draws upon the research and analysis made throughout the paper to make criticisms and to further substantiate the identification of design flaws. The chapter will highlight issues surrounding current design methodologies and the lack of consideration to the environment's ecological aspects, with a view to exposing a new approach to design for domestic-related ubiquitous systems.

The final chapter will summarise the findings made by the author, informed by the research and evaluations made throughout the paper. Recommendations will be made that answer many of the questions raised substantiated by further discussions and reasoning.

1. Background Research and Key Terms

This chapter looks at the themes and key technologies that revolve around the theme of "the internet of things". This relatively new concept (in practice) bases itself around embedding everyday objects with sensors and communicating with inanimate data sets to output some form of, or aid existing functionality.

1.1 Ubiquitous Computing

Approximately every two years computing power doubles whilst other technological advancements in areas such as communications bandwidth and storage capacity also see a similar performance increase. As a result of this trend, the future dictates that computers will get smaller, cheaper, more plentiful and subsequently, computing will become more ubiquitous.

As the leading technology companies try to keep up with Moore's Law[1], microprocessors and sensors can be integrated into everyday objects such as home appliances, children's toys, tools and even biological organisms such as plants and insects. When these devices become interconnected through networks, their data becomes accessible. This data can be utilised to increase the awareness one might have of their surrounding environment, the status of objects, tasks or even the future based on the analysis of different data sets. There are many examples where ubiquitous computing pervades aspects of everyday life, without being clearly visible and without impacting the natural processes involved. Stringer, et al. (2005) gives the example of the interaction involved in driving a car.

> *Here technology is employed not only in the car to ensure smooth running of the engine and safe braking but also in the traffic lights which control the movement of the car down the road and in the command and control systems which ensure that there is fuel in the pumps at the petrol station. This example*

1 Moore's Law states that "the number of transistors on a chip roughly doubles every two years. As a result the scale gets smaller and smaller" (Intel, 2005). This is the law is what drives the main 'blue chip' companies to increase speed and performance in the computing industry.

highlights another very important feature of many successful disappearing computing applications. The computers that work in them do not form a 'joined-up' system. Data does not flow through them end-to-end but is mediated by mothers on the school run, delivery trucks, shop assistants etc. In both cases, although they may have changed in many small ways, driving and shopping are still recognizable as the same activities that they were 50 years ago when no computing technology was involved.

Ubiquitous computing also extends further than hardware and physical computing, it is becoming increasingly more predominant in software. Solutions and client rich applications extend the boundaries of accessibility, allowing data to be available all the time utilising cloud computing, which this document will now discuss.

1.1.1 Cloud Computing

Cloud computing is yet another paradigmatic shift in the way resources and devices are accessed. Developing further the ubiquitous computing model, cloud computing uses a networked infrastructure where resources are made available on demand. By adopting thin client[2] solutions such as browser based software and VPN systems, machines that are connected can access the data without the need for local, expensive and high-end power consuming hardware.

Figure 1.1 illustrates the architecture behind cloud computing. The central 'cloud' is a network of networks that utilises all the communication channels available in the world. Considered as global networked infrastructure, this paradigm is changing the way businesses and consumers interact with computers and large scale systems. It also affects the way in which hardware and software services and infrastructures act with each other. The way in which systems are designed today incorporates this view of computing and as illustrated below, devices are becoming easier to connect to each other and larger systems.

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2 Thin Clients are traditionally lightweight computers or/and software that rely on a more powerful server to do standard computer tasks. It is a form of distributed computing that uses less power and resource on the client side and utilises dedicated hardware to perform complex computations over a network infrastructure.

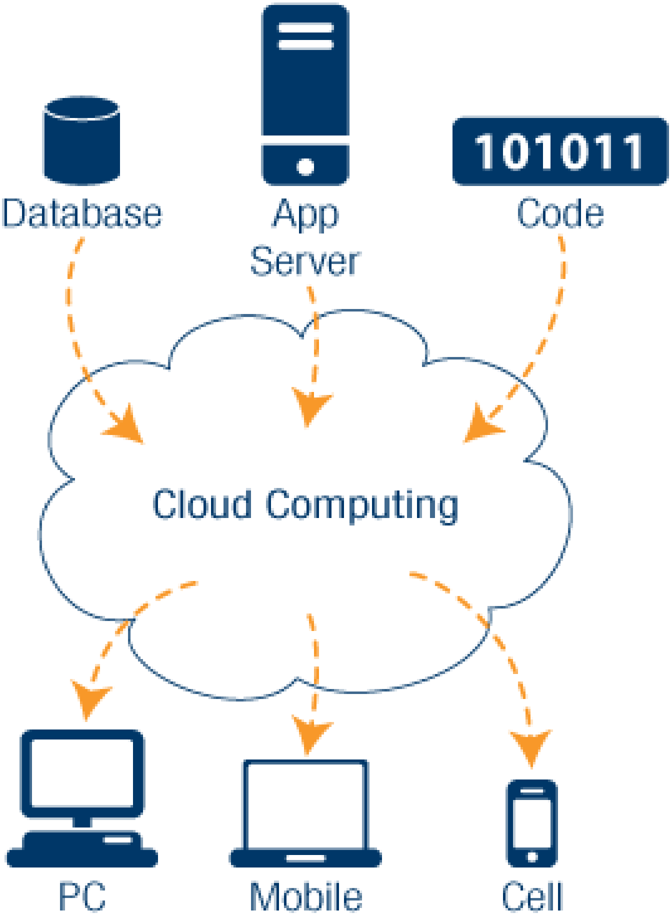

Figure 1.1 – Cloud Computing Infrastructure Overview

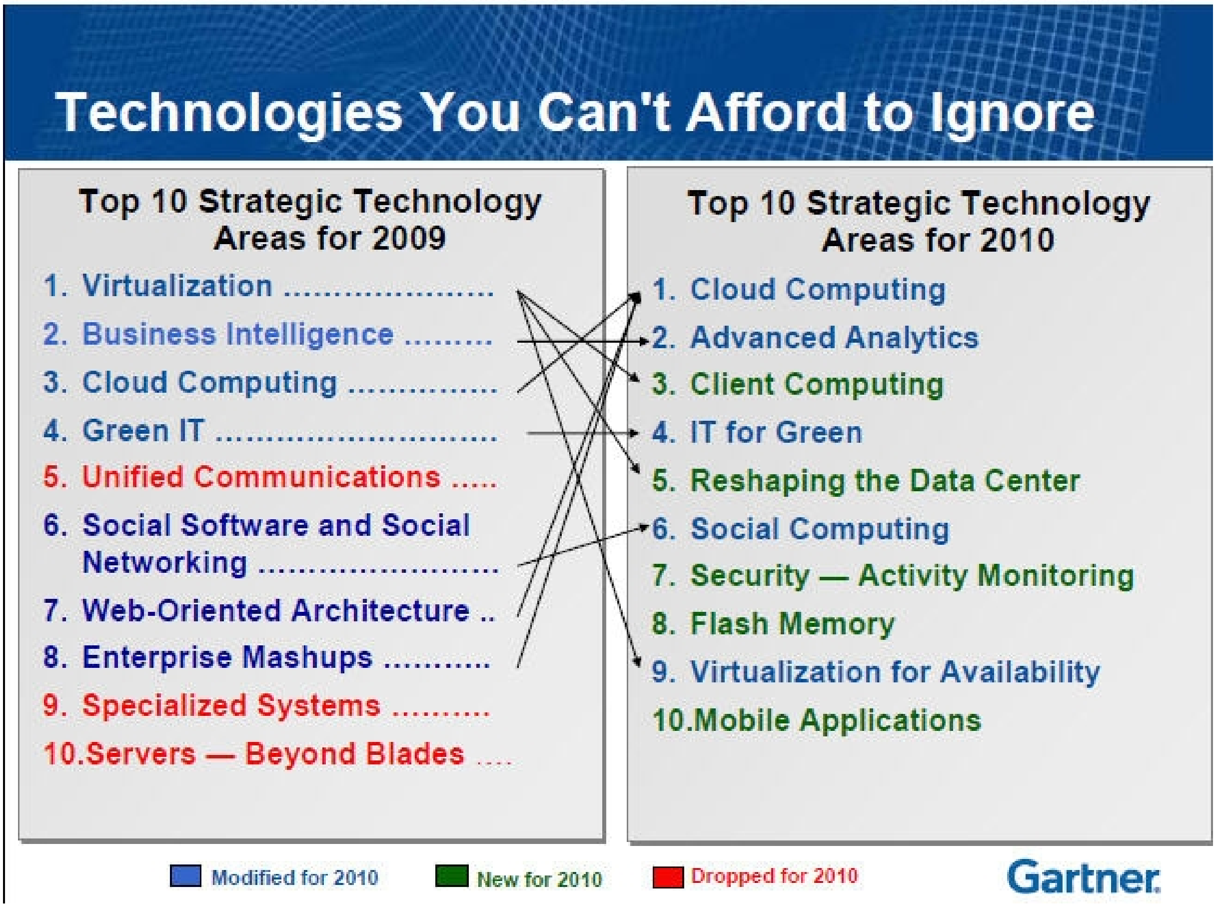

Figure 1.2 – Top 10 Strategic Technology Areas for 2010 (Gartner, 2010)

According to recent studies, cloud computing is considered to be the most important computing paradigm since e-Business (figure 1.2), with a predicted market size of a "quarter of a trillion dollars" (Gartner, 2008). It can then be assumed that, with all businesses aiming to embrace the change, the research and development focused around cloud computing will dramatically boost the rate of technological development. David Mitchell Smith discusses how *"companies invest billions of dollars in building up their core competencies, much of which goes into IT."* It can be further suggested that in the following years, cutting edge technology and new developments will ripple down through the business environments to the end point consumers. This will increase the capability and functionality of technology aimed at commercial and domestic environments, specifically those which address issues of environmental sustainability. Ubiquitous computing can therefore be the key to help generate and influence intelligent behavioural changes in the context of 'green' socialistic evolution. Since ubiquitous computing will pervade almost every aspect of human life, possible economic consequences, but also social boundaries need to be addressed.

To gain a better understanding of ubiquitous computing for end-point consumers, the next section will explore the current growth in the mobile telecommunications industry. This will aim to highlight the rapid development that is taking place for consumer targeted technology.

1.2 Mobile Technology

Mobile phones have grown since their initial conception in the late 1980's to become much more than a communication platform. They are now rich interfaces to larger systems with increased functionality and extend the interconnected world through a portable device. According to a report on mobile phone growth (BBC, 2010), "there are now more than five billion connections worldwide" with 20 percent of these occurring in the last 18 months alone. The report goes onto discuss that growth is expected to rise further to "six billion connections worldwide by the middle of 2010".

These statistics highlight how the technical capability for consumer's is rapidly evolving.

In recent years, mobile technology has experienced a sharp increase in computational power and has seen the emergence of a new type of mobile phone, named the smart phone. Smart phones boast a wealth of technological functionality and are flourishing in today's market, despite the impacts of the global recession. People are now technically capable of accessing information previously unobtainable, without being limited to location and equipment. As cloud computing becomes the main focal point over the next decade, smart phones will becoming increasingly valuable as an interface to additional information, whilst maintaining an ecologically supportive design. Recent studies on global mobile statistics (mobithinking, 2011), indicate that the mobile phone could start to replace the personal computer (PC) for many tasks.

> *The number of people accessing the mobile Internet is growing fast and is expected to overtake the PC as the most popular way to get on the Web within five years.*

To increase the value of these mobile devices, software systems and applications now need to scale horizontally and emphasise mobile technology to help support the growth for a more sustainable environment.

Paul Dourish (n.d, pp.2) argues that mobile phones need to be perceived and embraced as more than a communication platform and to be celebrated *"in their new role as personal measurement instruments capable of sensing our natural environment and empowering collective action."* For this socialistic change to occur, the technology needs to be distributed to the areas which have the largest impact, the home owners and users. In the next section these issues will be addressed in the context of government agendas.

1.3 Government Focus on Climate Change

The following section highlights the level of focus energy expenditure and green house gas (GHG) emissions have at a governmental level, specifically in the household sector of the UK. Global warming and climate change are issues which affect all nations and as such are only resolvable through collective effort. The UK Government had set targets to reach by 2010 to reduce the energy consumption of the country by 9 percent (NAO, 2008). A report on the "Energy cost of PCs on standby" (Long, 2006) states that "...our equipment on standby produces a total of 3.1 million tonnes of CO2." . This further reveals the collective impact minor and unnecessary actions can have on the environment.

1.3.1 Household Sector Analysis

Household energy consumption accounts for almost 30 percent of the total energy consumption for the UK which equates to nearly 27 percent of all carbon emissions. These facts highlight the importance of this specific sector and the impact it has on the UK's contribution to climate change. The means to achieve lower energy consumption for households will be in the form of increasing consumer efficiency with energy expenditure. by the National Audit Office (NAO) indicates that. In order to meet these targets, consumers need to be able to monitor their energy usage and adapt their lifestyles accordingly. By increasing the awareness one has of their household appliances and home environment, the previously mentioned targets should be achievable. As of yet there is no clearly defined government strategy for action or a system outlining which parties will be paying for the changes. What more can be done to empower end point consumers to make a change and to adapt to greener lifestyles?

The next section highlights a collaborative effort between businesses and governments to enable the creation of new standards which can drive real change in the field of ubiquitous systems.

1.4 Smarter Planet

Building on the principles of ubiquitous computing and using their brand influence, International Business Machines (IBM) have recently spearheaded a new global initiative called 'Smarter Planet'[3]. At the core of this initiative are three main elements; instrumented, interconnected and intelligent. Within this initiative there are many smaller 'themes' each targeting a specific industry or problem but built on the same three elements. For example 'Smarter Healthcare' specialises in developing solutions aimed at medical establishments such as the National Healthcare Service (NHS). Using technology such as radio frequency identification (RFID) patients can be tracked and data can be transferred between patients and nurses autonomously and ubiquitously, reducing workloads and time spent on routine tasks. Intelligence can be applied to the received data to aid diagnosis and support medical decisions.

In the 'Smarter Energy and Utilities' theme, IBM "help influence and define the standards that allow inter operation in industry" (Caffrey. J, 2011). It is responsible for developing and supporting the development of a number of solutions for local governments. Solutions such as; work scheduling to reduce carbon emissions from travel, and home energy monitoring and integrated home networking, to connect with home appliances. The latter example is the type of action the government are taking to target and enable end-point consumers to reduce their carbon footprint.

As technology becomes more advanced and more accessible, newer initiatives such as smarter planet are easier to implement en masse, where it is most effective. As ubiquitous computing is the basis for creating a smarter planet, promoting the growth of sustainable, cheaper and faster technology is key to penetrating the end-point consumer sectors and promote change in households. Referring back to the mobile phone growth, it is apparent a new type of interface which is becoming embedded into society can now enable these large scale infrastructures and solutions to target areas

3 IBM are considered a world leader for both business and technology, they have the power and leadership status to influence global changes through industry and as such are a key reference for the verifiability of this document.

previously inaccessible. Also referring back to cloud computing, it can be suggested that this paradigmatic shift, using smart phones is a viable option to interface more complex systems.

Now the facts have been established and the evidence suggestive that change is still a long-term proposal, the author will now explore other elements that are typically disregarded

1.5 Key Terms and Definitions

Human-computer Interaction (HCI) is the study of design, construction and implementation of human-centric interaction with computing systems.

Anthropology is the biological, social and cultural study of humankind.

2. Integrating Social and Spatial Aspects into Technology for the Domestic Environment.

In this chapter the author discusses the different theories and models relating to the field of spatial design, specific to the home environment. Furthermore, the social models applicable to this environment will be evaluated against the use of technology in the home. Drawing upon demographic research and key theorists, the author will establish that these aspects need to be fully embraced to help conform to the design of future home systems.

The home is considered a space where inhabitants feel most secure and degaged. It is an environment where true natural behaviour exists and whereby the inhabitant feels to be the superior figure. Unlike the working environment where most behaviours and actions are driven by money, the domestic environment is a place of freedom and privacy derived from one's social profile. Bollnow explains that a necessary condition for an "anthropological function of the house" within the whole context of human life, is the feeling of security. Only as an inhabitant can a person discover their own cognitive content and be fully human (Egenter. N, 2009).

Through the exploration of how the space is used, structures and social activities can be revealed. These social structures can further influence the design of technology solutions that can be implemented to support the reduction of carbon emissions.

2.1 Social Spatial Models – Understanding the Environment

The home is an environment which consists of various sub-environments that are labelled as rooms. Rooms have different connotations depending on the social status of the inhabitants. For example in a family house with children, a child's bedroom is a place psychologically belonging to the child, where that child sleeps and plays. A childless family might label that room as a study and use it for working or learning in a quiet and secluded environment. In essence the room is the same room, but the social activities that go on in that room are derived from the demographics of the inhabitants.

Rooms may be also considered private or public depending on the way they are labelled and used. For example a living room is considered a social space available to everyone within the household, this is also reflected in the naming of the room.

It is worth noting these examples are generic, but what can be firmly established is the social status of the inhabitants, does in fact change the way sub-spaces within a domestic environment are created and subsequently utilised. Research on how the domestic space is used by different demographics, within a family unit, is crucial for implementing tailored systems into households. Little research has been done which integrates approaches from architecture, anthropology, sociology and behavioural studies which can conform the design of future home systems.

The following sections explore the different approaches and models related to the study of how these spaces are used.

*2.1.1 Anthropological and Behavioural View of Spatial Usag*e

The family as a unit can be described as a social group consisting of parents and children; the relationships that exist within this unit, and how these relationships are embodied within the way domestic space is used. For the purpose of this paper, the majority of examples will be based on an average family in the UK. “The UK family: In statistics” reveals that there are 17.1 million families in the UK, of which 71 percent are headed by a married couple (BBC, 2007). Further studies from the ONS highlight that a further 79 percent of this demography live in a mortgaged house and have, on average, 1.8 children. It can be suggested that the majority of homes in the UK are therefore occupied by families with children.

In anthropology the aspect that defines how humans behave is culture (Rappaport, 1968). It is possible to evaluate how meaning and space ownership is agreed upon by inhabitants and how then to best implement a ubiquitous system that supports environmental sustainability.

In the household relationships and activities between spouses, siblings, companions and friends determine how spaces are divided and used. The kitchen for example can be described as a place of work and a necessity to fulfil the need to feed and provide for one's self and their dependants. In most cases it is not a place where people relax but a space within the home which is constantly being used. Out of all the spaces it is also the one that is used the most (Adams. C, n,d) and is also the space which uses the most electricity (Anon, 2011).

Considering meal times, most UK families eat at particular times of the day, times which are psychologically, culturally and biologically determined. At these times the kitchen space is used to prepare food and the other spaces in the house become unoccupied. From an energy point of view, all the appliances in the other rooms should not be in use. The reality is that most devices are left on, whether on a standby mode or due to human intention. The implications of these minor actions usually go unnoticed by the inhabitants and as such are not counteracted. If the status of these devices was known by a central ubiquitous system, intelligence could be applied, cross-referencing the spatial behaviours of the inhabitants and could be subsequently turned off. Supposedly 'smart systems' do not address these behavioural patterns within domestic spaces and as such become ineffective at times.

Taking the bedroom as another example, the functionalities of the room are limited to sleep and relaxation. A private space in nature, the bedroom is the room used the least. If all inhabitants are asleep, the devices in the house should mirror this action by also sleeping. A central system that has the power to turn devices on and off and cross reference the spatial and inhabitant behaviour, would be capable of providing such a function. In the Psychotropic House , the author describes a house that interacts and learns from its inhabitants and physically changes based on their behaviours. (Ballard. G, 1971).

> *The first PT houses had so many senso-cells distributed over them, echoing every shift of mood and position of the occupants, that living in one was like inhabiting someone else's brain*

Understanding human-spatial behaviour is just one element that can influence the design for domestic systems. The other important field of study is human-computer interaction.

The next section discusses the communication channels and interfacing options people have access to in their everyday life. It further explores how these can be used to establish a two-way dialogue with ubiquitous systems.

2.2 Human-Computer Interaction

Human-computer interaction is a field study that is important in understanding the cognitive attributes human interaction with computing systems. This section explores this field of study and applies it to the context of increasing human awareness of environments and sub-systems; as well as user feedback and notification systems. Adhering to the theme of domestic media, the author will explore how social models and theories overlap with the recent paradigm shifts in computing.

Scenarios where human-computer interactions occur are increasingly varied, as the paradigmatic shift in ubiquitous and cloud computing pushes smaller and embedded technology into everyday environments.

2.2.1 Communication

By intervening and adopting the use of the same communication channels as the inhabitants, a dialogue can be performed with the house and subsequently a new relationship between the domestic space and its dwellers can be established.

As previously mentioned in chapter 1, mobile phones are becoming an increasingly popular and accessible platform for end-point consumers to access data and cloud services. Instant Messaging (IM) is a communication model that connects two or more people together over a network such as the internet, and allows near instantaneous dialogue to take place. In recent years this has now developed from text based messaging onto video messaging. The implications of this on a social level are often overlooked however. A study by Pew Internet and American Life Project on teenagers in America, reveals that instant messaging and text messaging are now the preferred method of communication, collectively overtaking face to face chat (cnet News, 2010). This paradigmatic shift encompasses more than the social domain, instant messaging platforms are now being adopted by companies. Many large businesses such as Dell, Comcast and JetBlue, to name a few, have customer support services available through twitter. (O'Keefe, 2008). Further studies illustrate that the growth for IM users is set to grow between 2009 and 2013 to a total of 1.7 billion users (Hepburn. A, 2010).

The evidence suggests that these forms of media are no longer alienated from social life, but are becoming embedded into human culture. As these mediums are now becoming domesticated and more accepted as viable communication platforms, ubiquitous computing systems need to address the impact these paradigms can have with human-computer interaction to become more efficient. If dialogue can be established between inanimate data for example, a television and a person, the information that person can obtain from the dialogue could influence a behavioural change, such as turning the television off. Two things occur in this example, the first is a form of notification, an awareness has been made to the status of the object. The second is a description of a process and the recommended action needed. Using established and culturally embedded messaging platforms, the data exchange between ubiquitous systems and people could increase the awareness one has of their surrounding environment. To contextualise this for domestic spaces, a house could communicate with its inhabitants over channels which are embedded into the culture of the environment. This would allow for real-time notifications to be targeted and delivered in a form which is socially accepted by the respondents.

The concept of the 'home' is ultimately unverifiable and research needs to be conducted combining these subjected emotive connections to the house, substantiated by the inhabitants themselves. Mapping the underlying behavioural models with spatial design, a fully integratable ubiquitous system can be embedded into the home environment to help the inhabitants take control over their resource consumption habits.

Another element which the author has not yet mentioned is the additional knowledge that can be absorbed by the inhabitants if such proposed systems were to exist. The next section takes a more in-depth look at the subject of different learning models supported by the use of technology.

2.2.2 Ubiquitous Learning Environments

In an environment where ubiquitous computing pervades the life of the inhabitants, human learning models can be adopted to map behavioural changes and distribute cognitive processes to embedded computing.

> *The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." (Mark Weiser, 1991)*

In the scenario of turning a light off before leaving a room, currently this is something which is not considered a priority, due to the lack of awareness the inhabitant has. Using a form of system feedback, an inhabitant would learn that leaving the light on has a consequence, representative of a notification or another form of output such as sound or light. On a short term basis, these notifications provide the education needed for behavioural change to develop. On a long-term basis this very remedial task becomes habitual, the inhabitant no longer relies upon the information to carry out the action and subsequently the notifications are no longer needed. Repetitive tasks like this are made easier by ubiquitous computing and can cause physiological changes.

Habitual learning and ubiquitous systems, specifically relating to notification alerts, can therefore be a mechanism to provide behavioural change in the domestic environment. This can be further explored through experiential learning. This is where learning takes place through participating in activities. (Simons, et al, 2000). The authors go on to suggest that there is no leader controlling the learning and as such "circumstances, personal motivation, other people, innovations, discoveries, experiments etc. determine what and how one learns."

Becoming reliant on technology to notify people whenever they have done something wrong however should not be the aim for creating such systems. Systems for domestic spaces should be created with the aim of educating their audiences. If systems fail to address the need for behavioural change to happen on the physiological level, in the event of the technology failing, the subject has no knowledge to fall back on and has to re-acquire the necessary information.

To conclude, the learning experience derived from ubiquitous systems can indeed promote the necessary change, but it needs to be compiled in a way where it does not solely act as a tool for solving problems. Considering also the studies around how children learn from their parents, changes in the current generation can ripple down through future generations. It can therefore be suggested that the life span of the technology would therefore be embodied within the physiological change, passed down through future generations. The initial problem would therefore be solved and the technology would no longer be needed for that specific scenario.

3. Evaluating Current Solutions for the Domestic Space

In this chapter the author evaluates the current systems available to end-point consumers and the household sector, specifically those systems that target the reduction of carbon emissions in the home. The author will reflect upon the research and issues conducted thus far, and provide a critical analysis on these systems and provide suggestions for improvements where applicable.

Currently in the household sector there are not many solutions widely available to end-point consumers. The main driving force for growth in this area, stems from companies and their efforts to increase revenue "doing more with less is of interest to drive operating costs down" (Williams. V, 2011). Hobbyists and technology enthusiasts also help drive the growth, as they attempt to make their homes greener. The average UK family however are only presented with limited options, when the reality is there are many out there. Commercialisation of these unknown solutions needs to be adopted to reach out to the larger demographics.

In the context of ubiquitous systems for the domestic environment, the two most notable forms of technology come in either ambient intelligence or more commonly, data meters. Each of these will now be discussed in further detail and real world examples analysed and critiqued where possible.

3.1 Data Meters and Monitoring

Utility meters for gas, electricity and water have always been present in housing. It is these meters which are used by utility companies to charge home-owners on the amount of energy they use. Since the UK Government's recent focus on energy reduction in homes, UK based companies such as E.ON and British Gas have started to extend the accessibility of this data to the consumers. Smart Meters are more attractive and informative interfaces to the traditional analogue meters that are installed into the housing infrastructure at the time of construction.

> *Simply having physical characteristics is enough for a technology to convey social presence. But it seems reasonable to suggest that a more attractive technology (interface or hardware) will have greater persuasive power than an unattractive technology (B.J. Fogg, 2003)*

As Fogg suggests, these intuitive and aesthetically pleasing interfaces empower the consumers to see in greater detail the trends in their utility consumption. The interfaces display data relating to the current and historical consumption of energy, as well as contextualising that data in a way which is meaningful to the consumer. A consumer that is able to view how many kilowatts per hour they are using in real time, does not understand the wider implications. By contextualising this data to the cost the consumer is incurring, a relationship with that data is established and action can be carried out. It is this reciprocal relationship between one commodity (money) and another (energy) that makes these devices so effective.

Figure 1 displays the interface for one of the most recent smart meters, from a leader in the market. As it can be seen, there is a large amount of data available, but following the rules of user-interface design, a user can interpret and understand this data.

Drawing comparisons between the traditional energy meter, shown in figure 1.2 and the modern smart meters, it can be seen that the physical form as well as the data available has evolved greatly. The smart meter in this example displays more than just electricity information however. Both water and Gas utilisation can also be shown within the same interface with different configurations. A major element that has evolved is the physical design of the monitor. A stylish exterior and digital LCD display welcomes a user's attention, which can be juxtaposed against the traditional analogue model with its over crowded, unfriendly user interface. The difference in design stems down to the reason for creation. Smart meters have been designed around the ecology of human-centrism with the end-user in mind throughout development. The traditional displays were installed with the view that only professionals would ever need to access the information, and the needed knowledge would already exist. The cultural change behind technology in the workplace however now aims to bridge that knowledge gap with ubiquitous systems and empower consumers to act, delegating responsibility from the energy suppliers.

Figure 3.1 – Current Cost Meter, enviR

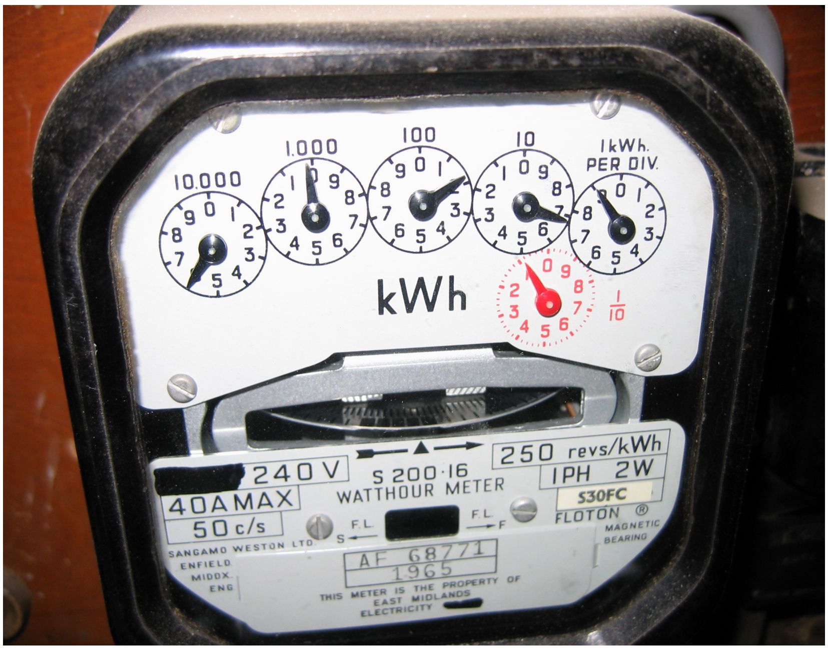

Figure 3.2 – Traditional Analogue Electricity Meter

The centralisation of this data obtained from the home environment allows the user to gain an understanding of the environment in greater detail, by seeing the bigger picture. This form of ubiquitous system is not without its disadvantages however. In figure 2 we can see a typical installation and system overview, which all smart meters for consumers are built upon. An evaluation from this reveals a severe limitation for this type of interface. As the data is visible only from a very small monitor, unless it is viewed constantly, it becomes redundant. An argument against this would be that the data is also available on cloud services and can be accessed by other social mediums such as mobile phones.

The same critique applies to this functionality however. If the data is non-obtrusive, its success is solely dependent on the user to take the action of looking at the information. The ubiquitous computing paradigm dictates that computing should become immersed in the environment, the criticism in the context of smart metering is that this paradigm seriously reduces the ability to perform its intended purpose, to increase awareness and promote behavioural and social change. If the connection between the human and the interface was more predominant and perceptible, data pushed to the user would be constantly accessible regardless of user and interface location.

Another criticism to this system, is that it does not encapsulate the ubiquitous concept of availability and accessibility. The data is limited to cloud based services and the physical location of the display-monitor. Referring back to the discussions on domestic environments, the home is a collection of sub-spaces, each attributed to different uses and ownerships within the family unit. Scottish Power (n.d), who are working with the government to implement this technology, state that the " energy monitor works best in easy-to-access areas like kitchens or other common areas...". As previously mentioned, the kitchen houses the largest energy consuming room in the home, but is not used all the time, as dictated by culture and biological necessity. During the periods where this space is not in use, the smart meter system again becomes redundant.

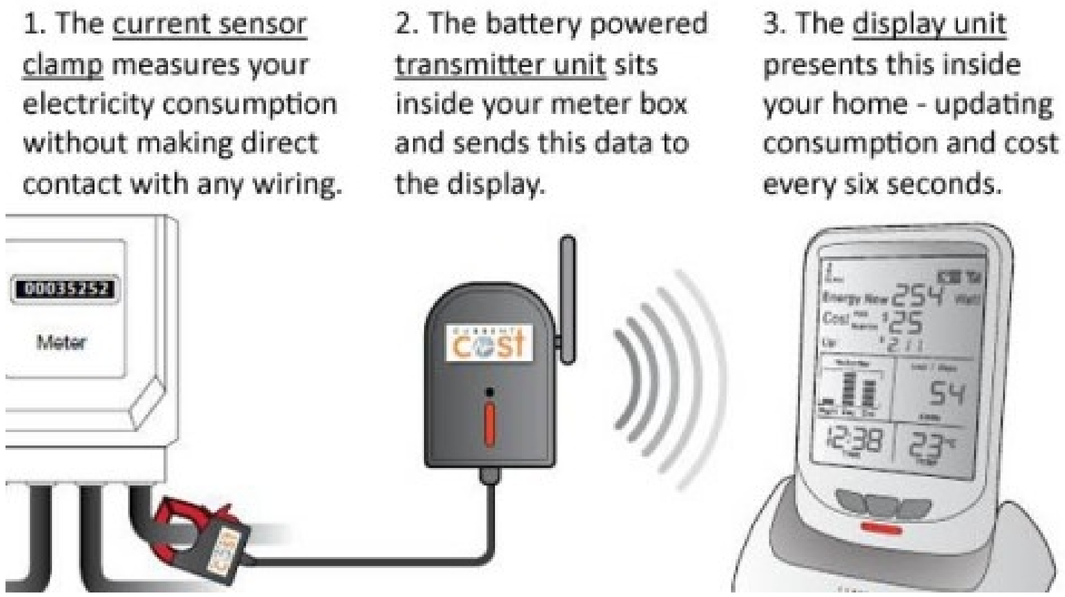

Figure 3.3 – Smart Meter System Diagram

3.2 Ambient Orbs

Another form of smart systems for the domestic space is ambient intelligence and orb technologies. These connect with users on a different psychological and social level but do not have the same level of commercialisation that smart meters have. Ambient orb technology follows the ubiquitous computing paradigm and embeds itself seamlessly into the environment. The processes are all hidden, but unlike traditional ubiquitous systems, the power of communication is achieved through obtrusive forms of output such as light and sound. The traditional view of information is often abstracted to the extent where patterns in data sets are mapped to different data models. It requires a level of understanding from the user, to understand this transformation but once the knowledge is transferred this form of sensing the environment becomes very effective. Hazlewood et al (2008) describes how the design of ambient orb technology is intended to be very minimal and *"perceivable outside the user's direct focus of attention."* This provides a level of pre-attentive processing without harming the functionality, relationship and culture embodied within the space.

Figure 3 illustrates an commonly adopted form of ambient orb design that displays real-time energy consumption within a house. It can be evaluated that on a design level, these orbs are very attractive which emphasises their ability to communicate with users. These devices also have an attribute which the smart meter interfaces lack, presence. In a space the subtle light changes become a decorative and calming decorative piece but also house important information regarding energy consumption. Most designs for ambient orbs use coloured light to represent the changes in energy consumption. The devices themselves do not intrude or change how a space is used, but spread their contained information throughout the entirety of the space. Contrasting this with the interfaces where a user has to be within reading distance to absorb the information, this ambient approach is far more omnipresent.

The main disadvantage to this form of data representation is its simplicity. The channels of information are usually limited and various orbs that manifest the same spherical shape but represent different data sets can become confusing. In figure 3.1 another orb uses the same communication channels as the energy orb. In this example colour is indicative of the temperature outside, but without knowing this beforehand there is no way to associate the visualisation with its intended data model.

As previously mentioned, there is a certain level of knowledge that is needed as a pre-requisite before this form of computing can communicate information to a user. This is an aspect the smart meter technology excels at, because the information is fully contextualised and intuitive. The ambient orb systems however are able to transfer their data constantly whilst a user is in the same room. The ambient orb takes the spatial models into consideration but lacks the ability to communicate multiple sets of data. The physical shaping of the orb is a property of design that is completely ignored. If different orbs were created in different sizes and shapes, that property in itself could be used to contextualise the visualisations that occur.

To conclude, both commercial and non-commercial approaches to ubiquitous systems for energy monitoring lack some form of vital component. Collectively all the ingredients exist and in order to create a fully influential and ubiquitous system for energy conservation, a hybrid between the two has to be designed.

Figure 3.4 – Energy Monitoring Ambient Orb

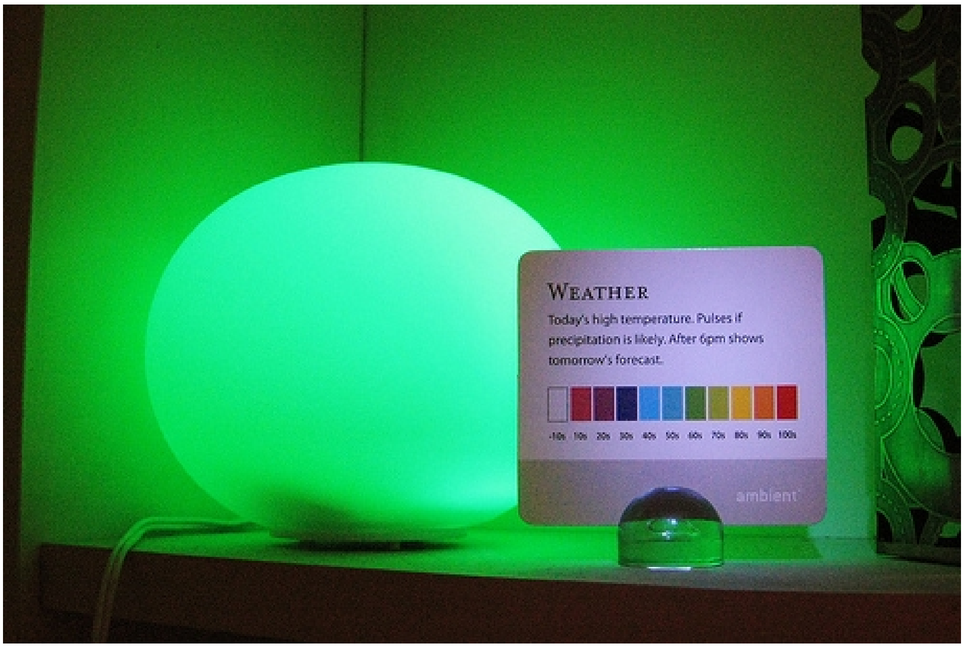

Figure 3.5 – Weather Monitoring Ambient Orb

4. Conclusion and Recommendations

In this chapter the author will evaluate the research and discussions and offer recommendations where appropriate. At the end of this chapter the reader is expected to have established an opinion on the validity of ubiquitous computing models for the domestic space; and the impact such systems can have to support environmental sustainability.

Domestic environments provide a space where there is a huge potential for adopting technology to enhance living conditions. Architectural automated services such as doors, heating and lighting reduce the time spent on trivial but, collectively time consuming tasks, giving an inhabitant more free time. Ubiquitous systems are now pervading into the culture of human life, but to be effective, systems need to be human-centric in nature and consider aspects of human cognition and domestic spatial models. It is only when all the requirements are collected that a true specification can be created and subsequently a system designed. Currently it can be evaluated that there is a noticeable divide between commercial and non-commercial solutions. Not all reasons for this have been discovered in this paper, but evidence supports that money and empathy for the environment are two of which, influence different design outcomes for domestic systems.

The paradigm shifts in computing and emerging technologies are establishing frameworks. Systems have the potential to collaborate and work towards the same goals. In chapter 3, two approaches were highlighted that attempt to address the energy that is wasted by consumer behaviour in the home. Both approaches adopt different methodologies and are both effective and ineffective in their own ways. What needs to happen is a hybrid system that manipulates human perception and peripheral cognitive capabilities, as well as communicating meaningful data through adept channels which are easily absorbed. The social living space needs to be further studied and solutions need to address how sub-environments are used to support the transferral of knowledge and the location of interface points. Alternatively interface points need to be distributed through multiple technologies and offer similar views of the same data. The mobile phone is currently an untapped resource for home targeted ubiquitous systems. The development of cloud computing can see devices such as smart phones becoming more integral to the way inhabitants interact with data about their home. This portable technology has already embedded itself into human culture and such should be the bridge designers and developers manipulate, to break the barriers between people and data.

A system which is present throughout the entire house and based upon the information delivery principles of the ambient orb systems, could enable a more accessible and non-locative platform to connect with its inhabitants. Referring back to the example of the psychotropic house, the illusion of an established dialogue as described by Ballard, could help to further breakdown the barriers of human-computer interaction. If a house can engage with its inhabitants through methods natural to them, the inhabitant's perception of the house is transformed and a relationship established. It is this socialistic approach which ubiquitous systems today lack, and substantiated through the arguments raised.

An environment working in situ with people, mediated through ubiquitous systems would be able to resolve the main problems surrounding household energy consumption. Consumer values regarding; energy consumption, ideological views on energy wastage and the education to support pro-active behaviour, are severely overlooked in solutions available today. Empowering the consumer through increased awareness and education is the true way towards promoting a sustainable planet. It is the cultural and social change which will persist through future generations.

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Appendices

1.0 Interview with Jamie Caffrey

-Transcript-

Nick:

Your name, job title, short job description.

Jamie:

Jamie Caffrey, Client Technical Professional - Working with IBM sales to provide technical support and enablement for customer opportunities

Nick:

How does the Energy and Utilities unit/dept address the need for smart systems for domestic spaces? (examples would be great)

Jamie:

Main work in IBM UK is evaluating and responding to the governments proposal to set up a Data Communication Company (DCC), that will be responsible for the collection of daily readings from 'smart' electricity and gas meters across the UK.
At present, this activity is in proposal phase, and no supplier has been chosen by the government. IBM intends to bid as a supplier, and to this end has created the UK smart energy cloud in partnership with Cable & Wireless (further details here: http://www.ibm.com/smarterplanet/uk/en/smart_grid/article/smart_energy_cloud.html)
With regards to domestic spaces, we are working with our partners in the Smart Metering arena (such as Landys & Gyr, Itron, Secure Meters, Energy ICT, etc).
Various bits of work are underway around this, the main one being the creation of standards to allow meters to talk to 'head end' systems using a common format called DLMS (http://www.dlms.com/index2.php). (A head end is a server that receives meter

readings and communicates with up to 50,000 meters).
We are involved in various working groups and standards bodies inputting into these standards. Other relevant standards are Zigbee and ZWave for inter operation with Home Appliances, as well as the TAHI initiative (http://www.theapplicationhome.com/)

Nick:

What are the main challenges for implementing solutions into UK households?

Jamie:

- Lack of defined government strategy as of yet, this is still going through consultation phase
- Lack of agreed standards
- Cost, who is going to pay for all of this?

Nick:

How does IBM work alongside the Government to help achieve European and Global targets for the reduction of CO2 emissions? (again any case studies would be great)

Jamie:

There are various bits of work we are involved in, too many too list across too many areas!!!
In general we help influence and define standards that allow inter operation in industry, increasing competition between vendors. In order to differentiate, environmental impact is now a factor that is taken into account.
We also develop a number of solutions for local government and public sector that allow for 'things' to be done more efficiently, for instance work order scheduling. This results in less miles being driven, and hence a reduction is CO2 emissions.
Have a look on our smarter planet page for this, there are a lot of examples there under smarter cities.

1.1 Interview with Victoria Williams

-Transcript-

<u>**Nick:**</u>

Your Name, job title, short job summary.

<u>Victoria:</u>

Victoria Williams, Technology Manager for Telco, Energy & Utilities for IDR.

A Technology Manager's role is to enable ISVs on IBM technologies, hardware, software and middleware. They are responsible for the technical relationship between the ISV and IBM and are the first point of call for technical queries that ISVs may approach us with. The TM can provide access to relevant expertise and support for the TM to help them to achieve their objectives.

<u>**Nick:**</u>

In what ways does IBM support the growth for greener IT, specifically for the household sector?

<u>Victoria:</u>

Significant R&D in this area, particularly with the launch of Smarter Planet.

Smarter Planet initiatives focus on 'smarter' solutions which are typically driven by industry. So plays such as smarter cities, oil & gas, water and E&U could impact the household sectors.

This could be a useful link for further info on those industries:http://www.ibm.com/smarterplanet/us/en/overview/ideas/

<u>**Nick:**</u>

In your experiences, how has the focus in the computing industry shifted to greener IT? Why do you think this is?

<u>Victoria:</u>

In some cases. In my experience the reasons behind this are usually cost driven rather than 'greener'; e.g. consolidation of server environments to avoid extra data centre expenses where possible. Basically doing more with less is of interest to drive operating costs down.

<u>Nick:</u>

Is there any apparent growth for IT solutions specifically aimed at domestic spaces?

<u>Victoria:</u>

Potentially within the E&U sector. UK energy retailers now offer in home display units obviously. There could be much more emphasis on this as the UK government moves UK Energy Retailers towards smart metering. Hildebrand are a recent example of this, case study URL below. This could be useful to you and is publicly available: http://www-304.ibm.com/easyaccess/fileserve?contentid=206288