Internet-based Energy Management Services: Prototype design of user's interface

A thesis submitted for the degree of Master of Science

Energy Systems and the Environment

Aggelos Niarhos

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Mechanical Engineering Department

University Of Strathclyde in Glasgow

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Abstract

The emergence of the “smart home” will create opportunities for new players to provide a range of advanced value-added services for residential users. New technology and deregulation of the energy industry are accelerating the development of Internet based energy services.

This thesis deals with an internet- based energy management service that will provide control and monitoring of energy consumption in the residential sector. Its aims are to stimulate interest in energy efficiency, by identifying ways to save money, energy and the environment.

Taking into consideration the typical consumer requirements of such applications, a custom-designed Energy Management Internet Service is proposed, as a service to domestic energy consumers. Three energy services would be combined together providing monitoring, control and information capabilities.

In order to control energy consumption and costs, regular and reliable records of energy use should be maintained. Monitoring is the collection; interpretation and reporting of information on energy use with a view to reducing energy consumption and associated costs. It is a powerful technique, which helps to identify waste and provides strong motivation for improved energy/waste management. Home appliances could also be controlled by the user or the utility at anytime and from anywhere in the world, thus helping to conserve energy.

From a technological perspective the underlying data models were identified contributing to the real implementation of the web site.

The main conclusion is that there is a clear need for real-life application trials that focus on how customers interact with new forms of information and communication technology. The results that will be obtained would be beneficial for consumers as an efficient and reliable service could be provided.

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1.1 Smart Home

The “Smart home” is one of the most challenging and potentially most rewarding business opportunities that exist in the world today. In the proposed "smart homes" a large number of sensors and actuators would be connected to each other, to make the home seem "intelligent". This intelligence could be of great assistance to people with a disability or to older people. Younger people without disability could also enjoy the comfort and benefit from the energy savings of a smart home.

At the same time, the market for home networking and residential gateways is being driven by low-cost computers, increases in the number of multiple home PCs, increases in the number of on-line households and increases in homes with broadband internet connections. The United States alone has over 100 million households, 44% of which are already connected to the Internet. Various market research firms have predicted that over 80 million US homes and over 400 million homes worldwide will be connected to the Internet within ten years. [1]

A home or working environment, which includes the technology to allow for devices and systems to be controlled automatically, may be termed a “smart home”. The degree to which this control is exercised is variable, being a function of the cost, the person’s own wishes, and the type of building into which the technology is to be installed. Homes which can automatically adjust the temperature, the level of security and permit efficient communications to the outside world, are of obvious benefit to all, providing they do not go too far and affect the freedom of choice of the person living within them. Once these homes are connected through a broadband connection such as a cable modem / DSL, considerable benefits are possible: The utility companies could automatically and remotely control various power, water, and gas facilities. Home appliances such as air conditioners, refrigerators, washing machines, clothes dryers and ovens could be monitored and controlled from inside or outside the house. Lighting and entry sensors, motion detectors, fire and smoke alarms, health care systems, and many other products and services could be connected. This would allow the house to be fully controlled and monitored by its occupants or their designated service providers from anywhere, at anytime, thus optimizing the efficiency of equipment and maximizing the quality of life and safety of the house and its inhabitants.

Given all these advantages and potential benefits the question arises as to why smart homes are not being built on a large scale. Several factors contribute to the fact that they are still a rare phenomenon. High costs have been mentioned as one of the key factors in the past but also lack of standardization and lack of information to the end user have been a strong influence. However, costs have been reduced enormously in recent years and some degree of standardization is under way. This has already led to larger demonstration projects and has raised awareness amongst the various actors in the field. It seems that we are finally on the threshold of a breakthrough in the area of smart home technology. [2]

1.2 Research Objectives

The energy and utility industry is facing major changes. The market is becoming liberalized and deregulated and customers can often choose a supplier. The rapid progress in information technology (IT) is creating new service opportunities in customer's homes.

Improving energy efficiency requires a fundamental change in energy consumption behavior of a large number of individual house owners. The underlying hypothesis in the present work is that energy consumers would change their behavior if they were provided with answers to questions such as:

- “How much energy am I consuming?”
- “Is my energy consumption increasing or decreasing?”
- “How much does it cost me?
- “Am I a high consumer of electricity?
- “Am I consuming more energy than other consumers in my area?
- “How much would I save by operating larger appliances overnight, e.g. washing machines?”

To achieve maximum benefit of an energy service to homes it is important that questions such as these are answered, perhaps in an interactive window.

The user interface is the single component in such a systems, upon which everything else will be judged. If the interface is confusing and badly designed, the system will be thought of in that way. Indeed, to make such a system appear simple is an extremely complex goal to achieve. It is, nonetheless, very important to do so. Whilst the implementing technologies may be similar, the interface must be appropriate to the special needs of the user.

Crucial issue in identifying, designing and implementing new services of the kind outlined earlier include those such as values, acceptance and trust.

This project is concerned with the design and deployment of a new energy service that would provide remote control and monitoring of energy consumption, through a standard Internet Browser.

The primary objectives of the project are as follows:

1. Design of a web-based user interface to help consumers identify the best ways to save energy in their homes.
2. Definition of the underlying data model required for the real implementation of the web site.

References:

[1] James A. O'Brien, "Introduction to information systems", McGraw-Hill, United States of America, Copywrite © 2000

[2] Smart homes homepage, http://www.smart-homes.nl

This chapter describes the infrastructure of a new energy service system. Overview of the current energy market in this field has also been included. Moreover, there is description of the possible energy services that could be implemented in the future.

2.1 Residential Gateways

For the real implementation of the electronic services, several key technologies, products, and customer attitudes must come together to enable an integrated solution at the right cost with the right level of security and ease of use needed for mass adoption. At the heart of this solution is what is often referred to as, the "Internet Home Gateway".

The Internet Home Gateway is one of the most critical components in bringing the Internet home vision to life. The primary role of the home gateway is to act as a bridge between the external Internet network and the internal home network thus bringing all of the appliances, computers, and entertainment systems into one fully accessible and well- managed environment.

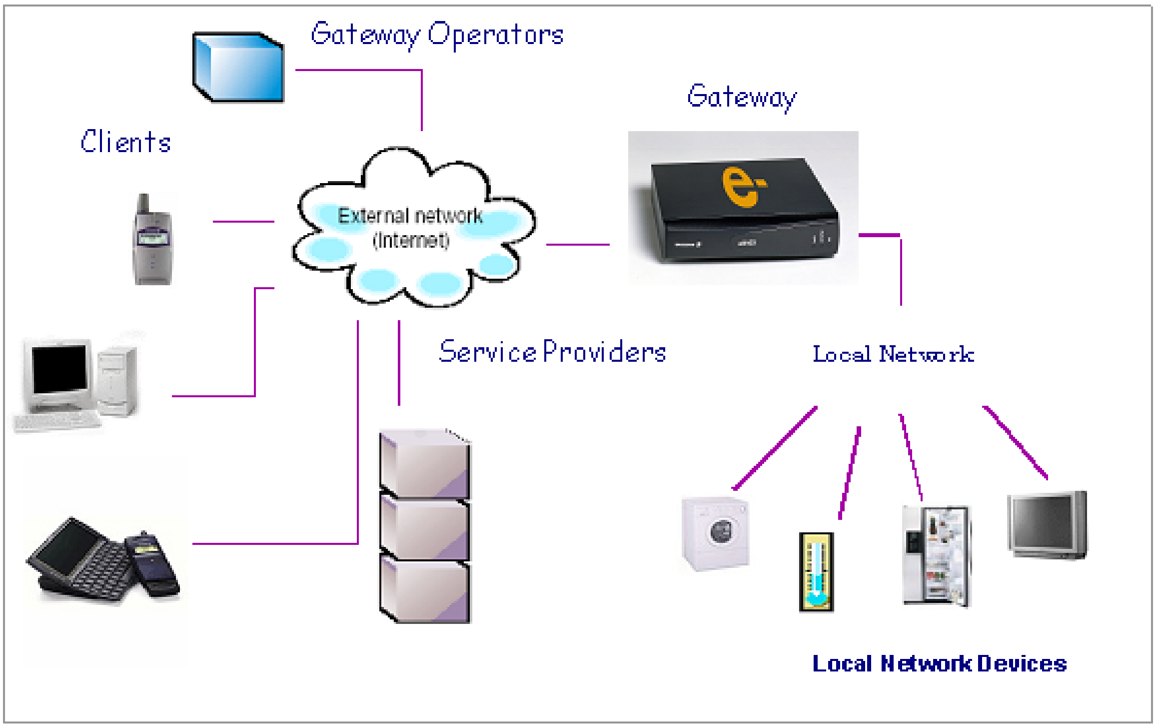

Figure 2.1 *The intended role of residential gateway*

The home gateway must also play several roles in the "self discovery" of devices, execution of logic for each individual home, scheduling of events and activities, action on events and a full range of secure and personalized user interfaces. This would be necessary to allow home occupants to interact and access the various controllers, appliances, entertainment, and security systems quickly and easily from anywhere at anytime. [1]

Once all of the in-home appliances and systems are connected, there is a requirement for back-end systems residing at the utility companies, appliance manufacturers and service providers to extract and control information from devices inside the house. The information would have to be fully integrated into the operations and business systems needed to deliver the desired fully automated solutions. In addition, these suppliers would need to be able to upgrade, maintain, and reconfigure appliances inside the home without the need for sending service personnel to each individual home. This would have to be accomplished safely and securely so home integrity and safety is never compromised.

All household systems and appliances in the "Smart Home" would be networked on the basis of open service gateway technology standards (OSGi). From the burglar alarm, lighting and heating systems, all the way to the refrigerator, stove, washing machine and microwave – every device could be controlled with WAP technology via the Internet or mobile terminal devices with Internet capability.

2.1.2 The Gateway Market

Because of its capability to distribute broadband access throughout the home to multiple devices, residential gateways are expected to have a fast adoption rate. According to the Cahners In-Stat group, the market for residential gateways will jump from just over $100 million in 2000 to $5 billion in 2005. At the same time, The Yankee Group estimates that nearly half of all US home utilizing a network will be using residential gateways. Market drivers such as low-cost computers, increasing number of smart appliances, abundance of online services and more mobile lifestyles will create the demand for residential gateways. [2]

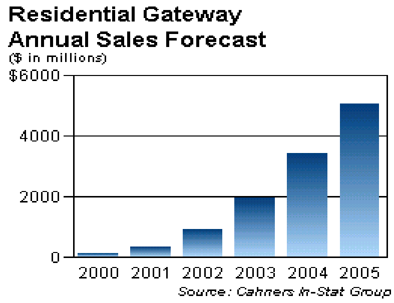

Figure 2.1 *Market forecasts*

2.2 Opportunities for e-services

The emergence of the "smart home" is creating opportunities for incumbent and new players to provide a range of advanced value-added services for residential users. Technology and industry deregulation are rapidly changing the way companies (who address the residential market) define and conduct their business.

As consumers become increasingly sophisticated and mature in the use of information technology, they are also growing accustomed to having their informational needs satisfied instantaneously. New technology, changing industry and consumer maturity are combining to accelerate the development of this nascent market of e-services to the home. The market seems to favour an open e-service platform that allows several independent service providers to share the same infrastructure in order to reduce cost. In a likely market scenario, a third-party network operator would assume responsibility for operating and maintaining a complete industry network as shown in figure 2.2.

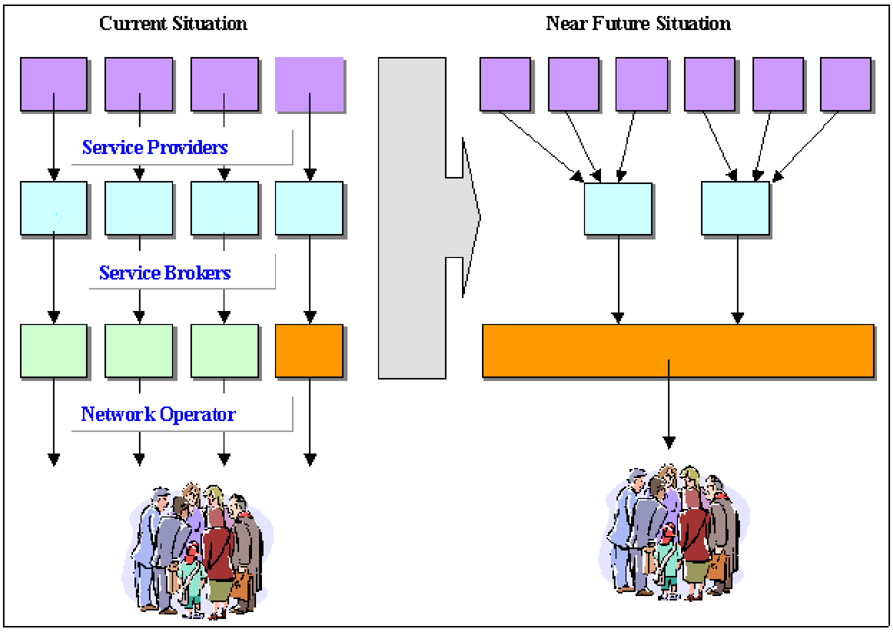

Figure 2.2 *Industry Structure*

In this e-service network, potential operators would include telephone operators, Internet service providers (ISP), cable TV operators, and utilities. Service brokers and third-party application developers would be other players in the scenario. The network operator is likely to play a leading role in creating the e-service industry network and to put an open e-service infrastructure in place. This is because:

1. Individual service providers have little incentive to invest in and maintain a large service network. Their primary focus would be on the provision of services.

2. The strength of the network operator depends on the number of service providers using the network and an operator will therefore try to keep the platform as open as possible.

3. A strong operator business case facilitates consumer subsidies and accelerates the adoption of the new technology.

An industry value system based on an open, e-service infrastructure for the home stands a strong chance of creating a scenario in which consumers, service providers and network operators can share in the creation of value.

Ericsson's view is that the e-services market will take off where high consumer value and low impact on the access network intersect. [3]

2.2.1 Distributed Services System Architecture

The distributed services system architecture, as illustrated in figure 2.3, focuses on the fact that a network management system is required in order to coordinate the messages in the network. Figure 2.3 also indicates new types of browser based access devices for the end user.

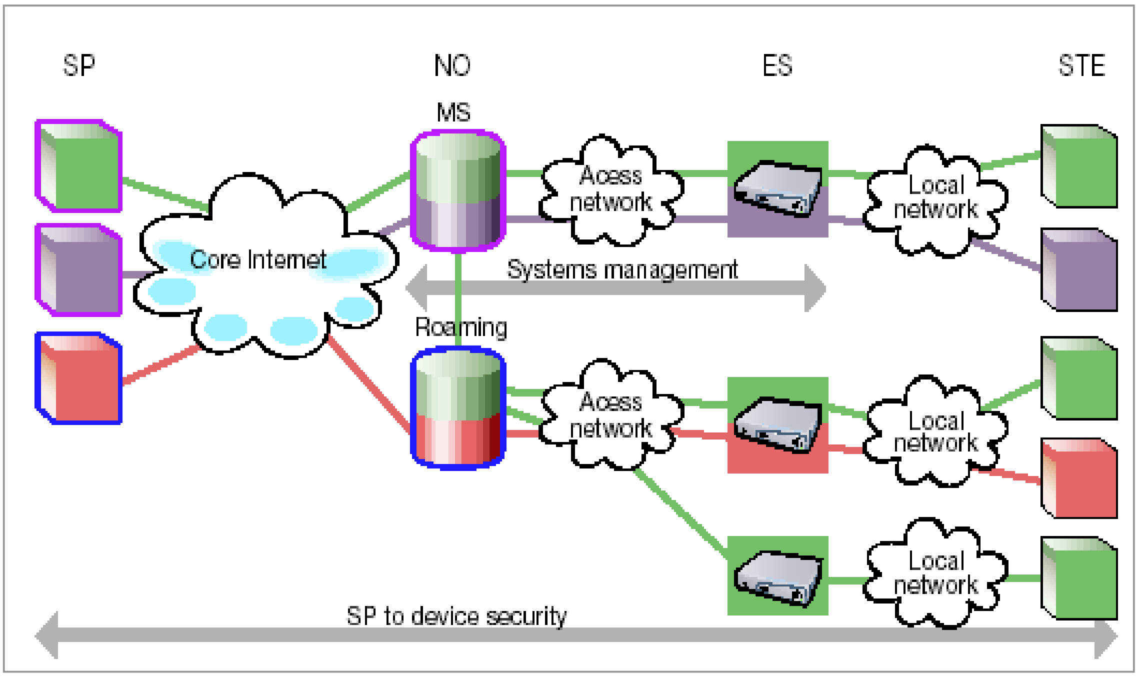

Figure 2.3 *Services System Architecture*

The system architecture comprises of the following entities:

Edge server (ES)

The edge server provides the basic Internet access and application environment that allows the SP agent to control devices on the local network and to communicate with the SP. Distributed computing and control functions makes the SP agent in the gateway resilient to network failure and also reduces the requirements for access network bandwidth and availability.

Management system (MS)

The management system is a key tool for the NO. It allows the NO to control edge servers and the service applications that run on them.

Network operator (NO)

The entity that operates and maintains the system service registry, network of service access points and edge servers. The NO sells network access to service providers and can have roaming agreements with other NOs to provide a global service network. Examples of potential system service providers include network operators and Internet service providers.

Service provider (SP)

The entity that furnishes services to end-users. The local component of the service is implemented using Java applications that run on the edge server (and optionally in the management system and at the site of the SP). Potential service providers include electric utilities, security companies, electronic media and banks.

Service terminating equipment (STE)

STEs are service end-point devices located in the local network. A broad range of devices must be supported, ranging from simple sensors for temperature and moisture to actuators or power switches and more sophisticated devices for user interaction, e.g. keyboards and screens.

All devices are connected to the edge server through one or more local networks. [4]

2.2.2 Electronic Services

The first services likely to emerge would cater for the homeowner sector, which is both large and significant in most developed markets. By definition, homeowners have often met a certain economic criterion, namely the ability to afford or secure financing for a home. In the homeowner sector, the primary sets of homogeneous consumer needs that could be met by the e-service infrastructure are those of communication and entertainment, security, energy management, home automation and home care.

1. **Communication and entertainment services** are likely to be the fastest developing of the five-homeowner e-service applications. These would provide pay as you play advanced Internet based entertainment services. This includes perfecting and caching stock / news feeds, on demand-audio and video services as well as traditional financial services. Here the gateway would manage the connection and billing between the online service provider and the in home delivery equipment.

2. The **security services** market is relatively mature, although we are seeing a shift toward bundled integrated systems, and new players from the telecom and energy industries are entering the arena. These are used to remotely monitor and control security services utilizing standard web infrastructure. These security services could be as complex as that used in a large office building or as small as those provided to a home. In this scenario the gateway would be the focal point for connecting the central office security systems to the individual pieces of security equipment on the premise.

3. **Home Automation Services** would provide a centralized point for automation of home entertainment and utility systems. The gateway would provide an integration and management point to allow JINI and/or HAVi devices to be deployed and managed
Key drivers for a home-automation application will be ease of use and the penetration of network-enabled devices. The primary business opportunity for service providers will be to bundle home automation services with the other emerging services.

4. **Health Care Services** would provide remote monitoring of patient state, metering of medication and emergency alarm services. Here the gateway would maintain a continuous connection to health-care workers at the local hospital as well as to mobile health care workers, such as ambulances and doctors. The gateway is used to monitor patient health-care equipment and notify health-care workers of significant activities. Home care represents a large, growing and relatively untapped market for service providers.

5. **Energy Management Services** in order to manage the peaks and valleys in energy usage. This service would provide for automated metering, remote control, and home energy usage optimization. In this scenario the services gateway would provide a coordination point to allow several JINI and other device technologies to interact and be managed from the utilities central office.

The primary application in the energy area would be automatic meter reading (AMR). When customers in the same local distribution network start buying from different suppliers, a need arises to measure hourly consumption by consumer, so that the suppliers can work out how much they owe each other.

Some countries, e.g. Norway, have opted for another model: so-called profile curves in order to solve the clearing problem. However, even in those markets there is much to be gained from AMR: consumers may switch suppliers, and a final reading would then have to be done. In other words, the number of manual readings would go up. Furthermore, the distribution companies have much to gain from AMR when it comes to network optimization, load balancing, and outage detection. In addition to AMR, new technology opens up opportunities for energy management services that help consumers reduce their energy consumption and/or increase comfort. [4]

2.2.3 Benefits

The consumers will benefit from reductions in costs of utility services, such as energy and security. Also, consumers will benefit from having access to a faster and integrated home LAN. Finally, consumers will benefit by having access to a wider range of advanced network based services.

The service providers will benefit because a new value point will be inserted into the home such that they can manage and deliver services to that are Operation Systems independent. Service providers will be able to brand and deploy services to an open standard based platform.

The service developers will benefit from the OSGi by having a consistent open standard to the delivery of their vertical services. Service Providers become part of new markets, protect current business, enter new value chains, build customer loyalty through selling multiple Internet based communications services per subscriber under one brand. The real-time, services economy is coming and the Open Services Gateway Initiative is a key market enabler.

Finally, the network operator benefits from increased traffic volumes in the wired or wireless telecom network, thus leveraging investments already made in his infrastructure. In addition they are able to offer additional value by bringing new services to his existing subscribers. They can also act as the broker of services from a multitude of service providers.

2.3 Energy Market

The market for residential energy services is negligible today, but is likely to grow dramatically over the next few years. The Energy services will be introduced into the European market when consumer awareness increases as to the existence of such services increases. Energy suppliers such as Scottish Power are challenging traditional methods of doing business and are adopting new practices. It will thus be possible to facilitate the entry of such new services. The strongest driver for change is deregulation in the energy industry, which is already happening today in the Nordic countries, the UK and California. This trend is inevitable in the rest of the European Union and the USA. Utilities are looking for new ways to create revenue when prices-and margins-are falling but are also seeking ways to ensure customer loyalty. At the same time new entrants from highly competitive industries, such as the retail and banking industries, see an opportunity to involve themselves in a potentially lucrative market.

A number of technologies for assessing energy use in homes have been available for a long time. The costs of energy monitoring and control in homes have so far prohibited a widespread use. Recently developed open-system and internet-based technologies such as the ebox-technology, have changed the situation. These new technologies have the desirable feature that the physical infrastructure needed for electronic energy services may be used by other electronic service providers as well.

Sweden is one of the most deregulated energy markets in the world. Nevertheless, Sweden's different energy distributors still measure the energy consumption manually once per year. Invoices that consumers receive in the time between are based on estimates of consumption. The actual consumption is not presented until the yearly measurement. With the rapid growth of technology, the consumption does not have to be estimated any longer. There is no need for manual readings since the GSM module (developed by Ericsson) communicates the electricity figures wherever they are wanted. In the near future the electricity figures could also be communicated to a web page on the Internet, where the consumer can easily read off the consumption and also compare the costs between different energy companies.

"Through increased knowledge of the actual energy consumption, more possibilities of savings are offered, when every saved kWh contributes to both cost- and environmental improvements," said Bengt Sundling, President of Enermet. [5]

2.4 Implementation Issues and barriers

The critical success factors for the implementation of such services, which relate both to consumer needs and technological requirements, would be as follows:

People's Trust

Security is one of the major barriers to expanding e-commerce applications. Consumers don't think about online security, expect in as much as a poorly informed business press keeps raising the issue to create fear, uncertainty and doubt in their minds. [6]
However, solutions are being developed. Together with GTE, IBM, Microsoft and other companies, VISA and MasterCard have developed Secure Electronic Transaction (SET), which will serve as a standard protocol for secure credit card transactions on the Internet. It uses

complex cryptography to transmit credit card information and digital signatures to ensure that both buyers and merchants are authentic.

People's trust in the new technologies is one of the main aspects that Service Providers need to address. Effective customer support and an understanding of the actual needs of the consumer will be the key to success in this new business environment. Furthermore there is a need for the implementation of new and more secure transaction technologies.

Educational

Consumers and society in general would have to get familiar with the new technologies and the potential lifestyle benefits of those services. Within the fast moving society there are citizens who are able to follow those changes and also those that are unable or unwilling. The online household users are those who have a certain level of education and technical ability to adapt to the new environment. The market sector of online households and specifically those who buy goods and services online represents only a small percentage of the total population in the UK and worldwide. There is a need for society to interact in a more efficient way and include as high a percentage of the consumer's population as possible. [7]

"Projected increases in broadband Internet access—although not essential to home controls applications—will have the benefit of educating consumers about home networking in general," said Reza Raji, Director of Business Development at Echelon.

Technological

Since the technology of interactive homes and appliances is still at the development stage, there are difficulties in evaluating the right time to enter the new market. Speculation has it that the technology will be available by 2005 should this actually happen, it will be seen as a milestone. On the other hand the use of compatible technology could be an alternative solution, pending the introduction of the new technology. There is a need for the development of new standards that will support the available technology. [7]

Another key parameter is the cost of implementation that would make it easier for the consumer to use the new emerging services. The new technological equipment (sensors, gateway, thermostats etc.) should be affordable to the consumers.

Furthermore, manufactures would have to design and produce Internet compatible appliances. Electrolux has already designed and produced such appliances but these are still at the experimental stage. More recently, LG Electronics introduced its Internet Air Condition - a Home network product that uses remote control technology that allows users to control appliances from outside of the Home via the Internet. In addition to that, Whirlpool this month said it will collaborate with Sun Microsystems to develop Internet-enabled refrigerators and other appliances using Sun's Jini device-networking technology. [8] General Electric and Maytag have said that they would incorporate Microsoft's competing Universal Plug and Play (UPNP) specification into their home products. Another point that needs to be mentioned is the appliance life cycle. An agreement would be required as to when the consumers would implement replacement of older technology appliances and the cost implications. [9]

2.5 Possibilities of new energy services

In the domestic sector, the energy services that were identified were associated mainly with control and monitoring purposes. These services related to the end user, i.e. the consumer and are described in the following sections.

2.5.1 Medical Monitoring and Care of the Elderly

Problem statement

Cold-related illnesses lead to an alarming number of deaths in the UK each year. Exposure to cold is estimated to cause 30,000 deaths a year in the UK. The causes vary, and include increased susceptibility to flu and other viruses. However, hypothermia is one of the most deadly cold-induced conditions and if not caught and treated early on, can lead to a rapid decline in the body's ability to function normally, resulting in death.

Hypothermia is a cooling of the entire body, usually to temperatures below 95 °F. During prolonged exposure to cold, more body heat may be lost than can easily be replaced by shivering and constriction of blood vessels, so the body temperature drops and hypothermia results. In young, healthy persons, hypothermia usually occurs only after extended physical exertion in cold, windy conditions. It can occur even at mild temperatures if exposure is prolonged. The body's natural defenses against the cold include the restriction of the flow of blood to the skin so as to prevent heat loss, shivering and the release of hormones to generate heat. These measures are limited and are usually inadequate to maintain body temperature in cold environments.

Mission Statement

Consumers would be able to monitor the inside air temperature of each room through a web page. When the temperature is low there would be a warning to the consumer, and he/she could take action. In the case of elderly people the system could be programmed in such a way that the heating system would automatically operate.

Furthermore if someone has a chronic medical condition, simple devices would let him/her check vital status, such as blood pressure, sugar or cholesterol levels at home. This data would be sent automatically to a doctor or other medical personnel. No clinic visit, would be necessary nor time be wasted sitting in a waiting room. It would be possible for the gateway to be programmed as a reminder to a patient to take prescribed medication i.e. medication type/dosage/frequency of dosage. [10]

2.5.2 Indoor Air quality

Problem Statement

The indoor environment is very important to our health and well-being. Outdoors air pollution that can damage our health. Indoor air pollution too can have deleterious effects. According to the Environmental Protection Agency (EPA), studies of human exposure to air pollutants indicate that indoor air levels of many pollutants may be 2-5 times, and occasionally more than 100 times higher than outdoor levels. These levels of indoor air pollutants are of particular concern because it is estimated that most people spend as much as 90% of their time indoors. Typical symptoms may include headaches, unusual fatigue, itching, burning eyes, nasal congestion, dry or irritated throats, and nausea.
Indoor air quality problems arise due to:

- Ventilation system deficiencies
- Tobacco smoke
- Improper temperature and relative humidity conditions
- Poor lighting
- Unacceptable noise levels
- Outside air pollutants

Mission Statement

To mitigate poor indoor environmental conditions, temperature, humidity, light, smoke, CO_2 and sound pressure sensors could be deployed. The data captured by the sensors could be displayed after suitable proper processing, on a Web Site. In such a way consumers would have the opportunity to monitor indoor pollutant levels. This would allow suitable measures to be undertaken to improve the situation, thereby helping to maintain a more comfortable and healthy indoor environment.

2.5.3 Control & Monitoring of energy consumption

Problem Statement

Energy Management and conservation have become very important in today's society. Several events have taken place to cause us to be more concerned about saving energy.

According to the *International Energy Outlook 2001* (*IEO2001*) reference case, worldwide electricity consumption is projected to increase at an average annual rate of 2.7 percent from 1999 to 2020. Household appliances already account for a considerable proportion of domestic electricity demand in industrialized countries. This pattern of consumption is being adopted in developing countries. Finding more energy-efficient ways of satisfying increases in energy demand has taken on a new importance in the debate on how to limit emissions of carbon dioxide. [11]

The annual electricity consumption in the residential sector has been increasing because of a change in lifestyle and the growing popularization of many electrical appliances installed within homes.

Studies have shown that the amount of power consumption in this sector is 2.2 times higher than in 1973 (1^{st} oil shock occurred this year).

Looking to the future, without major lifestyle changes it would be difficult to reduce energy consumption in this sector. For suitable supply and efficient management of electricity, it is important to survey what and how household electric appliances are being used and the pattern of their usage.

Mission Statement

The main objective is the provision of more effective energy management for the consumer. Energy management and conservation are the keys to using fuel and electrical energy in the most efficient way. Proper energy management can lead to big savings on the energy costs of a house. If fuel and electrical energy consumption are reduced, money will be saved as a result.

Because all devices and utilities in a "Smart home" would be linked via a residential gateway, consumers could closely monitor (through a Web site) energy costs for every kW of electricity, every gallon of oil, every cubic feet of gas that they use. Consumers would also be able to control their appliances, in order to maximize energy efficiency.

Equipped with that information consumers could save money and utilities would be able to offer pricing with discounts for off-peak use.

2.5.4 Benefits of Energy Services

Energy Services would provide a range of benefits including:
Environment - Reduced energy consumption, lower CO_2 emissions, one of the major causes of climate change.
Local Authority - Help in meeting their responsibilities under the Home Energy Conservation Act; tackling of fuel poverty and improvement in the condition of housing stock.
Housing Association - Improved services to tenants, lower energy bills and better quality housing.
Energy Supplier - An added value service to retain existing and attract new customers.
Consumer - Warmer homes, lower bills and better access to the benefits of the competitive energy market.

2.6 Related Work

A similar web site that was identified is the Home Energy Saver, which was developed by researchers at the U.S. Department of Energy's Lawrence Berkley National Laboratory (Berkley Lab). The Home Energy Saver (HES) web site is an interactive decision-support environment for residential consumers. Its aims are to increase consumer interest in energy efficiency and to foster market activities that capture those opportunities. The HES was the first Internet-based tool for calculating energy use in residential buildings. The site is divided into two main sections, *" Energy Adviser"* and *"Making it Happen"*.

The Home Energy Saver's *"Energy Adviser"* calculates energy use and savings opportunities, based on a detailed description of the home provided by the user. Users can begin the process by simply entering their zip code, and in turn receive instant initial estimates. By providing more information about the home the user will receive increasingly customized results along with energy-saving upgrade recommendations.

Furthermore it calculates heating and cooling consumption using the DOE-2 building simulation program, developed by the U.S. Department of Energy. The program performs a full annual simulation for a typical weather year (involving 8760 hourly calculations) in about 10-20 seconds, after the user assembles the necessary information describing their home.

The “Energy Advisor” calculates domestic water heating energy consumption using a detailed model. Users can see how household size, age of occupants, equipment efficiencies, and water inlet temperatures affect bottom-line energy costs.

In addition to calculating energy use on-line, the Home Energy Saver's “ Making it Happen” connect users to an expanding array of "how-to" information resources throughout the Internet. These modules help users successfully capitalize on the energy savings opportunities identified by the Energy Advisor module. These modules offer a host of links to practical information, ranging from lists of specific efficient products, tips about selecting a good contractor and information on what assistance your utility might have to offer. The site also features an extensive glossary and frequently asked questions module. [12]

Merits

The merits that were identified are the followings:

- HES allows consumers to enter information about their own homes in order to compute where energy is being wasted and what specific changes would result in energy savings.
- Since HES is web-based, there is no software to install.
- Users benefit from a dynamic information base unparalleled by resources that could be published on static electronic media.

- No membership is required. Users can begin the process by simply entering their zip code.

Limitations

During the exploring of the Web site the following limitations were identified:

- The user has to answer up to 30 questions on the size and characteristics of the house, to get a custom-tailored energy bill breakdown.
- Answers to frequently asked questions about home energy use, are in terms that not all the homeowners can understand.
- Sometimes the high traffic volume of the HES site cause delays or temporary site unavailability.

“The Home Energy Saver represents a fundamental departure from previous energy calculators because is Web-based. It brings together in one user-friendly package the analytical capabilities of many sophisticated calculating methods,” says Evan Mills, HES project leader.

2.7 Research Approach

Homes would be provided with sensors for measuring energy use for heating, household electrical energy, indoors temperatures and other properties, as illustrated in figure 2.4. Three functions can be distinguished here, (1) a data- acquisition part, (2) a data-processing part and (3) a data distribution.

In the data acquisition part, information is acquired from the sensors and converted into data. Usually, the sensors produce an analogue signal that needs to be converted into digital form in order for the data to be processed by computer systems.

The data-processing part contains all the necessary elements for converting the signal into the required form. This part often starts with filtering and amplifying.

The third part performs the data distribution towards to the gateway, where the information is required. The gateway acts as a bridge between networks: an external network (typically the Internet), and a local network consisting of for example, Ethernet, some kind of radio LAN or Blue tooth to reside between the Service Provider (SP), network and client servers. [13]

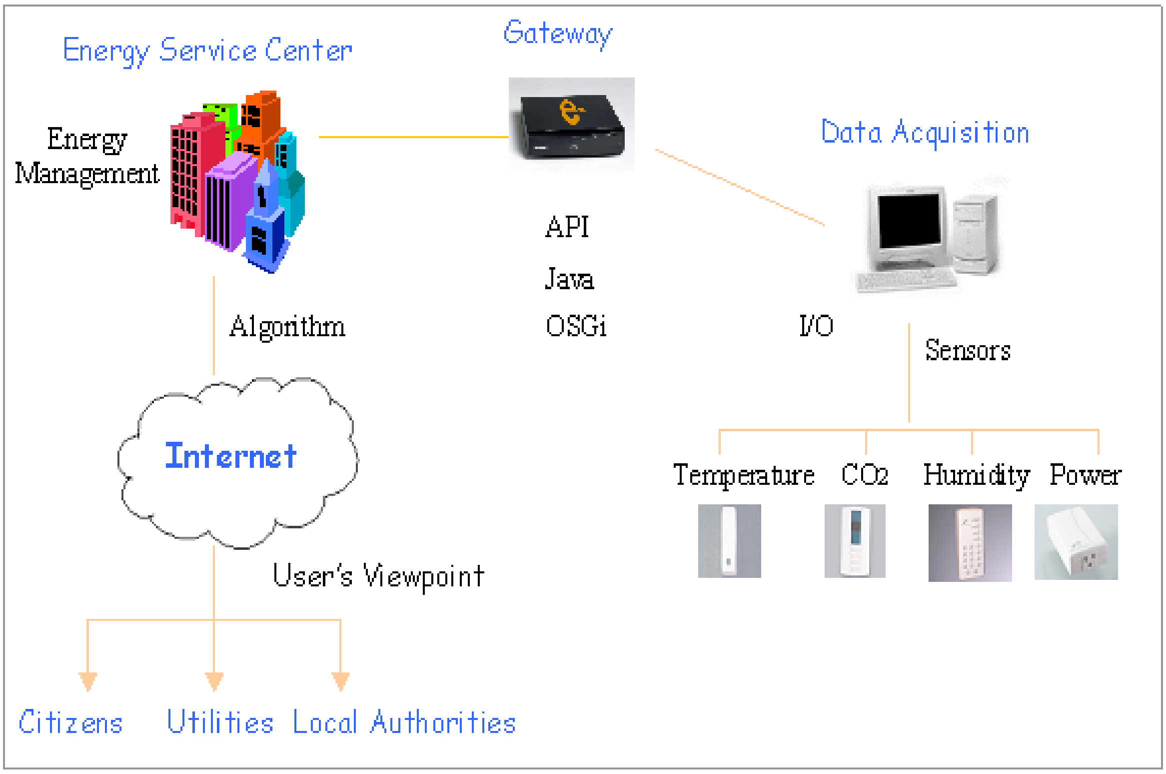

Figure 2.4 *Energy Service Systems*

The gateway then transmits the data to the Energy Service center for processing by the appropriate database management system before being posted on the Internet.

There are different interfaces, where data can be posted on the Internet depending upon the user's viewpoint. Typical web-browsers could be related to the end-users, utilities and the local authorities. Many monitoring systems are not utilized to their maximum capabilities and have been known to badly fail because of designed user interfaces. Therefore, the user interface is an important parameter for the successful implementation of the service.

This project is focused on the domestic end-user's perspective for the design of the interface and the identification of the underlying data models required for the real implementation of the web site as described in the following chapters.

References:

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[13] Anton F P van Putten, "Electronic measurement systems, theory and practice", Eindhoven and Middlesex Universities, IOP Publishing Ltd 1996

This chapter presents development of a Web site, which would provide residential energy services for control and monitoring purposes. The display information is nearer to the customer's value system.

3.1 Typical Consumer Requirements

Typical consumer requirements of such kinds of applications are related to reliability, utility, simplicity and security.

<u>Reliability:</u>

Whilst many seasoned PC users are used to their systems occasionally "crashing", this would be unacceptable for mission- critical services such as security and energy management. An emergency system would be required to automatically deployed, should such a situation occur.

<u>Utility:</u>

Home services must provide an obvious consumer value: Does it save money, help consumers to stay in touch, or make life more enjoyable? Consumers are becoming more aware of how energy use fluctuates and what they can do about it. Just as importantly, there is increasing awareness of how energy prices fluctuate. Many customers welcome opportunities to manage loads as a way to save on energy bills and for other reasons such as improving the environment.

<u>Simplicity:</u>

Home services must be simple to install, and easy to use. Services should be intuitive to learn and with an easy-to-use interfaces that inform the user as to how much money he/she spends on energy usage and how much he/she could save by controlling home appliances through the Internet.

Security:

Consumers do not tolerate invasion of privacy or hacking into mission-critical services by third parties. Effective controls would provide information system security, i.e. accuracy, integrity, and safety of information system activities and resources. Figure 3.1 outlines the security requirements that companies must fulfill in providing secure energy services using the Internet.

▪ Privacy	The ability to control who sees (or cannot see) information and under what terms
▪ Authenticity	The ability to know the identities of communicating parties
▪ Integrity	The assurance that stored or transmitted information is unaltered
▪ Reliability	The assurance that systems will be available when needed and will perform consistently at an acceptable level of quality

Figure 3.1 *Security Requirements for electronic Commerce*

Controls can minimize errors, fraud and destructive elements that may jeopardize the information systems that interconnect today's end users and organizations. Effective controls also provide quality assurance for information systems. That is, they can make a computer-based information system more free from errors and minimize the incident of fraud. This allows provision of information services of higher quality than manual types of information processing. This can help reduce the potential negative impact (and increase the positive impact) that information technology can have on business survival and success and the quality of life in society.

Monitoring systems can be established to ensure that such hacking activities are identified when they occur. Establishing such security systems is vital not only to minimize risks of system downtime, data loss or corruption but also to encourage supplier and customer confidence. Another step forward is the implementation of Data Protection Act (1984). This ensures individual privacy of information and has major implications for all data held in the UK.

3.2 Web Site Structure

The web site is designed to help consumers identify the best ways to save energy in their homes, and make the savings a reality. The first stage of the web design was to define the basic layout, as illustrated in Figure 3.2. The Start up page (Web Page 1) consists of an area where new and existing users can sign in, in order to proceed securely to other web pages. Thus ensuring privacy of the content. Furthermore there are two links: The first one relates to a demonstration of the system and the second to new users sign up.

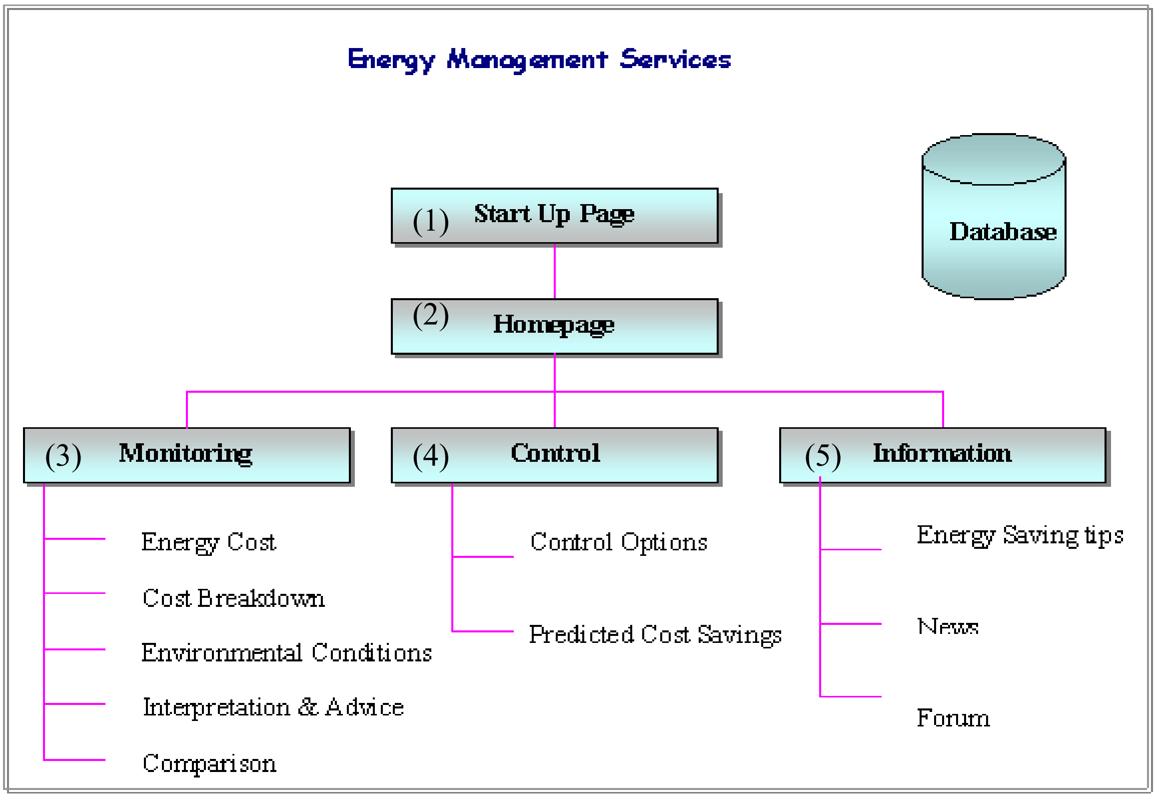

Figure 3.2 *Site Map*

The user, after inserting personal details, signs in to a private web page (Web Page 2). On this page there are links and a description of the services provided. There are three different energy services (monitoring, control and information), which are represented by the Web Pages 3, 4 and 5 respectively. The second stage was to define the content for each web page as described in the following sections.

3.3 Accessing the service

The web page as displayed in figure 3.3 provides general coverage in easy-to-understand terms relating to energy services. It is organized in such a way that the reader can understand how various types of energy services could be used in their homes and what benefits can accrue to his/her wallet and the environment.

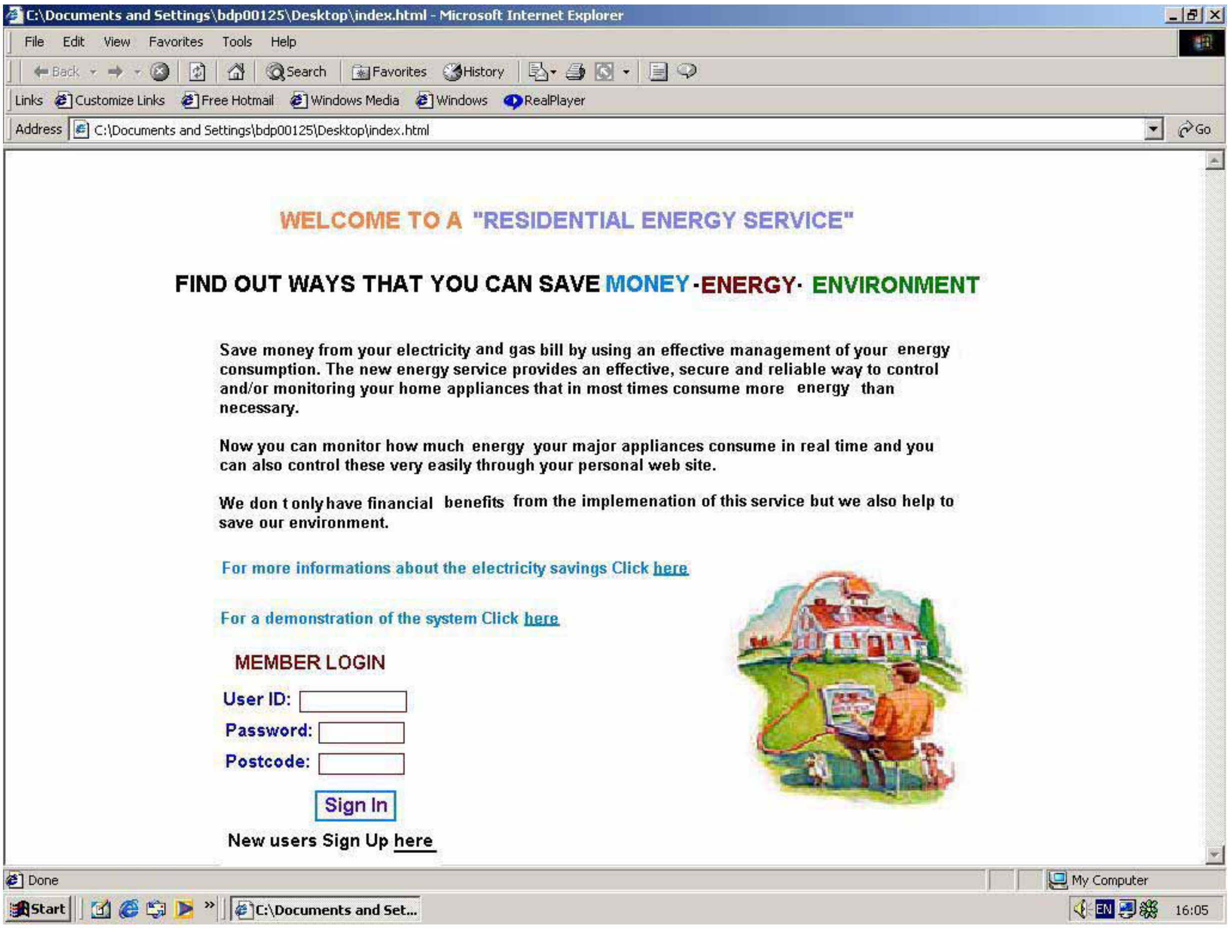

Figure 3.3 *Display of the Authentication process*

The purpose of this section is to attract potential customers and to convince them of the benefits of implementing, implementing, the energy services in their homes. The key message is "FIND OUT WAYS TO SAVE MONEY- ENERGY-ENVIRONMENT". As we mentioned previously, consumers are concerned mostly for value of the service. For that purpose in particular, there is a link to another page that provides information about the energy savings that could be achieved and also a demonstration of the system.

Another typical consumer requirement is security and privacy of the data that is going to be displayed. In order to ensure security and protect the privacy of customers there is a section for member login. For new users, there is a link to a registration page. Once the new user fills in the required fields and submits the registration form, he/she automatically becomes a member with a unique ID, password and a reference number.

3.4 Energy Services provided

Once the user supplies his/her unique identification number and password, which is validated by the service provider, he/she then enters into a secure area as illustrated in figure 3.4. In the top frame of this web page, the user's details appear, confirming the privacy of the content.

The homepage acts as a conductor of an orchestra, in this case "orchestrating" the various energy services. The first energy service is called "Monitoring", providing reports of energy costs (gas & electricity), cost breakdown, interpretation, and environmental conditions on specified dates determined by the user. The second emerging service is the "Control" of the operation of home appliances offering the energy saving opportunity. The information associated with news/energy saving tips, on-line forum, feedback and expert advice, comprise the third energy service.

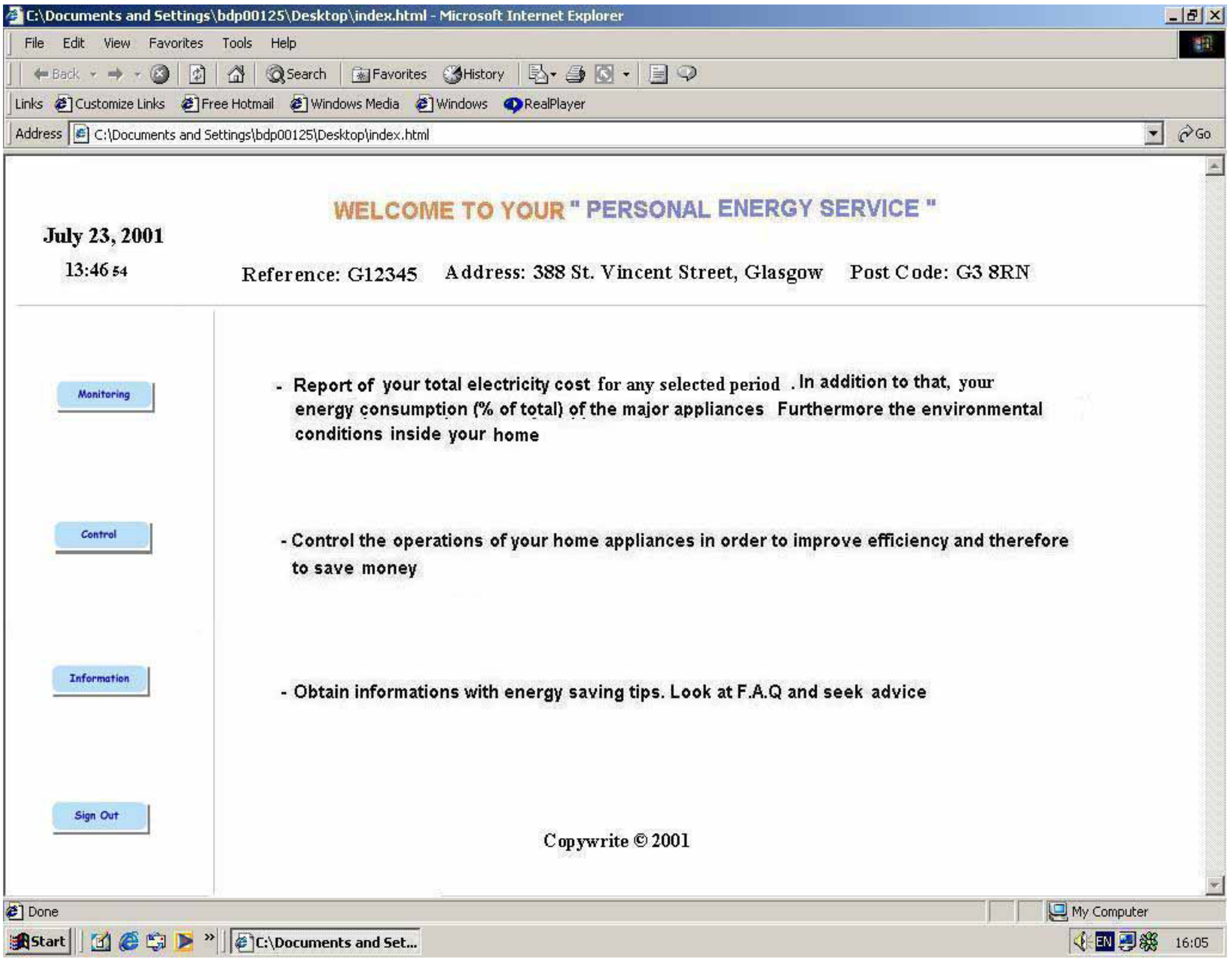

Figure 3.4 *The homepage for new energy service*

The following sections deal with a closer look at the above energy services, giving the main characteristics and the display content.

3.5 Monitoring & Targeting

Monitoring is essential element of energy management. It usually requires an initial investment in additional metering, followed by a regular commitment to the collection and analysis of data. To control energy consumption and costs, regular and reliable records of energy use should be maintained. It is important to discover where energy is being consumed and where it is being wasted. The causes could then be diagnosed and cured, leading to reduced energy consumption and costs. Government figures suggest that monitoring and targeting (M & T) can lead to savings of between 5% and 25%.

A typical Monitoring & Targeting (M&T) system should:

✓ Record energy consumption and any other factors that affect energy use (such as building usage, environmental conditions, etc.).
✓ Compare a site's energy use to previous years, to other homes in the estate or to a target energy performance.
✓ Alter sudden changes in energy use patterns as soon as possible, so that any increase can be investigated and corrected if appropriate.
✓ Produce regular summary reports, especially if there are many sites, to confirm performance and show savings achieved overall.

3.5.1 Energy Cost

A fuller understanding of energy use in a building may be useful, for example, if there is a problem. The house may have a poor energy consumption record including unexpected energy bills. Figure 3.5 shows an example for the Energy cost part, as it would be displayed on the web site. The users usually have contracts with their energy suppliers in order to receive their energy bills at specified periods. Some users may receive their bills monthly, others quarterly but there may be periods during which they don not know how much their energy costs may be. The energy distributors still measure the energy consumption manually once a year.

The invoices the consumers receive in the time between are based on estimates of the consumption. The actual consumption is not presented until the yearly measurement has been taken.

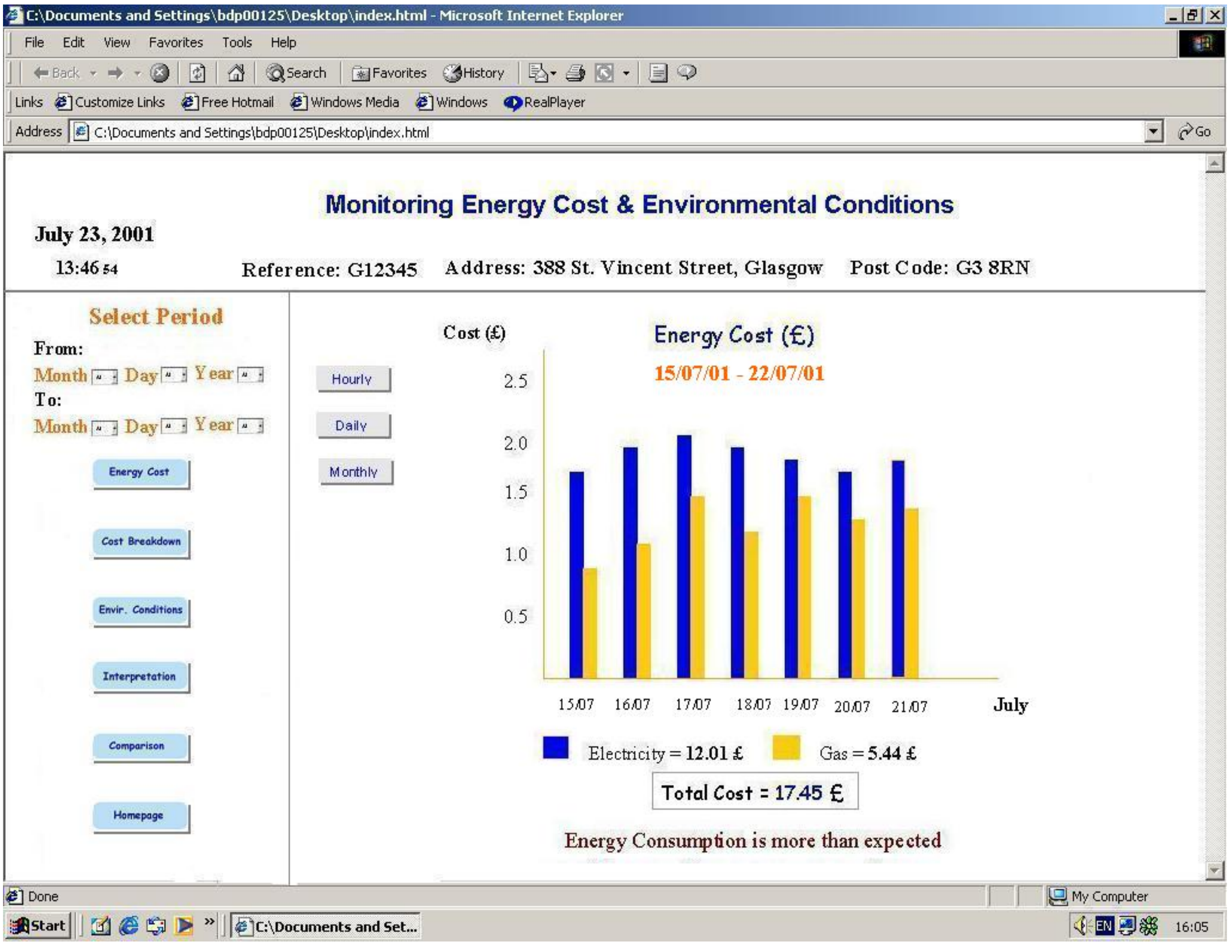

Figure 3.5 *Display of a daily Energy Cost Information*

This service would provide the energy cost in real time and the users would be able to manage their energy consumption more effectively. The user is in much better control of the energy costs and can act faster when changes occur. Moreover, improved meter management would ensure that the meters were properly sized. It would also helps to detect theft and reduce bill adjustments. The revenue forecasting is improved by tying detailed consumption information to production data and expected billings.

The use of energy in a house can be viewed in terms of the quantity of fuel or type of energy purchased. The cost of energy used in a house is calculated according to a rate charged by the supplier and the measured quantity of energy use by type. Typical quantities include gallons of oil, cubic feet of gas, and kilowatts of electrical energy. The user on this web page has to select the period, over which he/she wants to monitor the energy cost. Typical monitoring periods would be hourly or daily, with quarterly and annual summaries. A chart with the energy cost in pounds against period would then appear on a specified area. Various charts, which are the result of the chosen monitoring period, are presented in Appendix A2.

3.5.2 Deciding priorities

A general understanding of what electricity and fuels are used for helps to concentrate attention on priority areas, especially where the use of a particular fuel is particularly high.

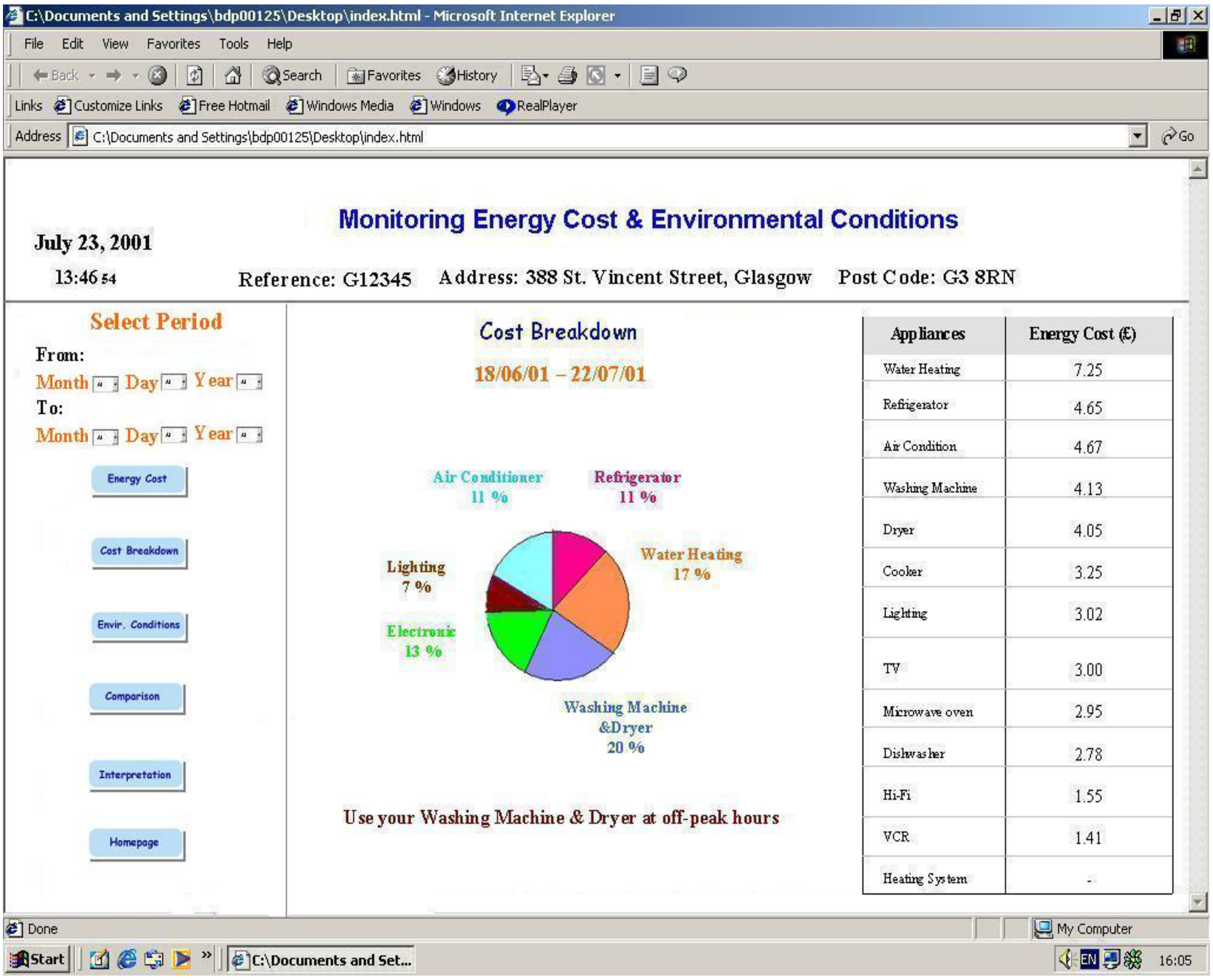

Figure 3.6 *An example of a typical Energy Cost breakdown*

The pie chart as shown in Figure 3.6 represents the way in which the customer uses energy. When the user selects the monitoring period the energy cost and cost breakdown are adjusted by that setting. In that example, the greatest use by far is for water heating, accounting for 17% of the total energy cost. However, lighting and electronic appliances take up a surprisingly large portion of energy. Below the pie chart there is a comment relating to the energy cost, so the user can easily pay attention to the priority areas in order to reduce consumption and therefore save money. On the right hand side of the page a list with the energy cost in pounds (£) appears for each appliance.

The priorities should be determined following on from an assessment of likely opportunities for savings, the value of energy involved and the available resources. Priority can be given to areas where savings might be identified for minimum cost and effort, for example simple space heating systems.

3.5.3 Environmental conditions

The web page as illustrated in figure 3.7, relates to the environmental conditions. There is a display for mean temperature (°C), CO_2 (parts per million) and relative humidity (%) values for each room of the user's home in real time.

- For room temperature *above 18°C*, *CO_2 level less 13,000 ppm* and *relative humidity 30% - 50%*, the values appear with a green light showing that the environment is safe.

- If the temperature drops to between *12°C - 18C*, CO_2 level *13,000 – 15,000* ppm and relative humidity *20% - 30% or 50% - 60%*, then the values will appear with a yellow light, signalling a risk to health.

- If the room temperature drops below 12°C, CO_2 level above 15,000 ppm and relative humidity less than 20% or higher than 60 %, then the values will appear with a red light flashing continuously. If the values remain high for a long period of time, then an alarm will also sound, indicating that the room environment has become deleterious to health.

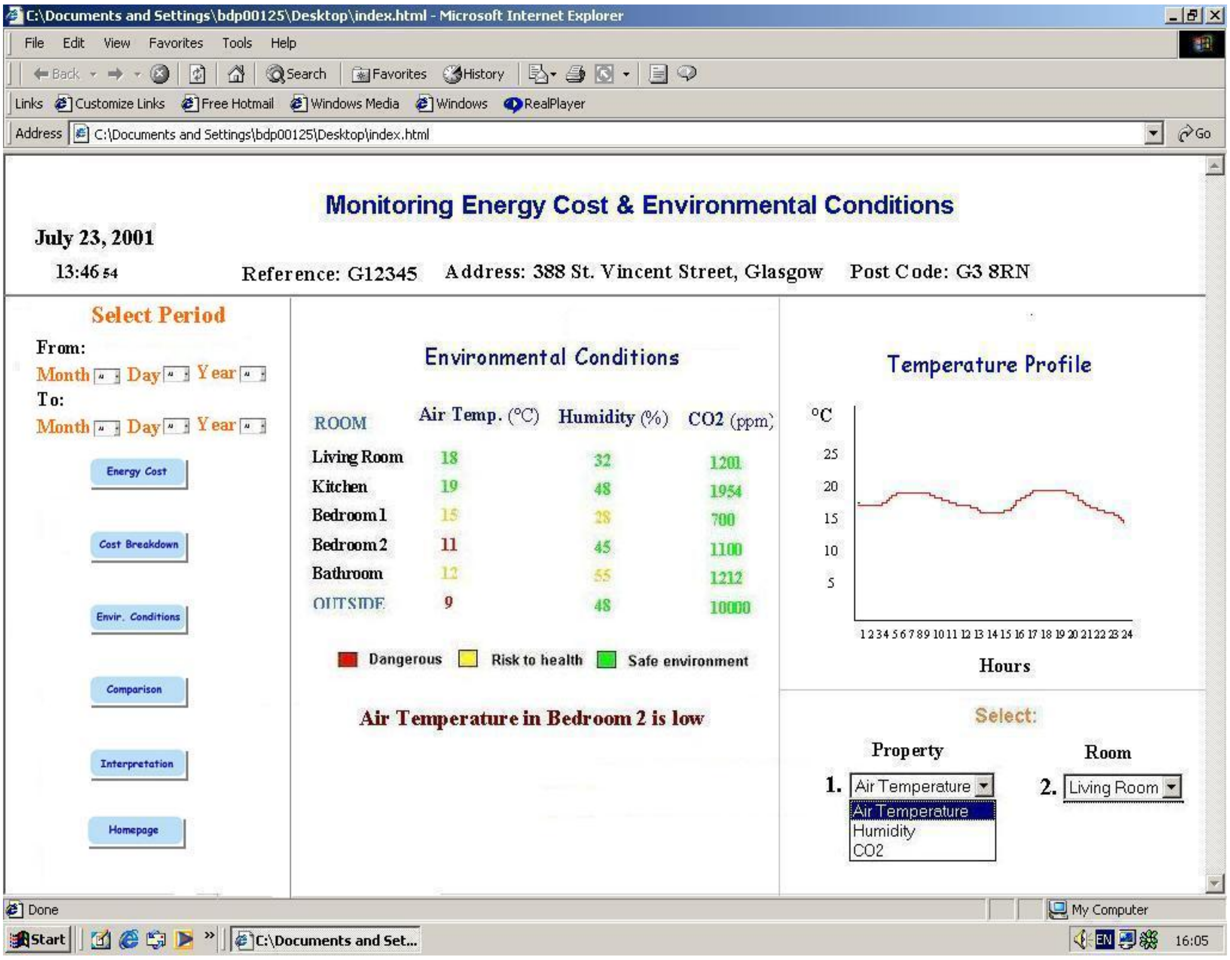

Figure 3.7 *Display of the Environmental Conditions*

In addition, temperature, humidity and CO_2 profiles for each room are also available. In this case the user has the chance to see the different profiles occurring at previous periods. Temperature profiles would help to identify:

- When and where incorrect air temperatures occur.
- Where equipment is operating for incorrect periods or is poorly controlled.
- Whether system flow temperature is appropriately matched to outside temperature, when simultaneous recordings are made for comparison.

The recording instruments must be located carefully if the results are to be interpreted correctly. The cold draughts, direct sunlight, and proximity to heat sources could all produce misleading results. With caution the results of even a short-term recording could give fair indication of what might be expected to occur in the near future.

Air Temperature

Air temperature is one of the parameters required to evaluate the thermal environment, according to ISO 7730. Moreover, it is one of the principal variables, which affects the energy consumption and cost, because operation of the heating or cooling systems is influenced by that variable. The heat loss from, or gain by, the home is proportional to the indoor-outdoor temperature difference. One method used to assess heating requirements for homes is to find, from weather data, the number of `degree-days' in the heating season. This is found by multiplying the days during which there is an indoor-outdoor temperature drop by the number of degrees temperature drop for each day.

Carbon Dioxide

It has been observed that CO_2 concentrations between 300-600 ppm are adequate, i.e., people don't usually notice whether or not the air is "stale". However, as CO_2 concentrations increase beyond these levels, one will notice ill effects. This is especially true if room temperatures rise and/or CO_2 levels increase above 800 ppm. As these conditions persist, fresh air will need to be introduced.

Usually in a home, the CO_2 levels can vary as much as 300 - 2000 ppm. Several studies have indicated that CO_2 does not seriously impact human health until levels reach approximately 15,000 ppm. This level is more than 40 times greater than the normal concentration of atmospheric CO_2. At extremely high levels, i.e., 30,000 ppm, (these concentrations are usually never reached in a standard home) the symptoms can include nausea, dizziness, mental depression, shaking, visual disturbances and vomiting. At extremely high levels, loss of consciousness may occur. The seriousness of the symptoms is dependent on the concentration of carbon dioxide and the length of time the individual is exposed.

Finally, CO2 is an asphyxiate. This leads to a condition in which an extreme decrease in the amount of oxygen in the body, accompanied by an increase of carbon dioxide, leads to loss of consciousness or death. Concentrations of 100,000 ppm or more of CO2 can produce unconsciousness or death.

Humidity Levels

Experts have developed “rules of thumb” to help homeowners make decisions regarding humidity levels in their houses. The limits should be used as guides only. Acceptable or comfortable humidity levels will actually vary from season to season, from house to house, and even between rooms in the same house.

People are generally comfortable in homes when relative humidity ranges between 30 and 60%. Below 30%, some people experience dryness in their nose and throat. Over 60%, the air begins to feel uncomfortably sticky. When it is below -10°C outdoors, the recommended indoor humidity level is 30%. Human comfort is one consideration for indoor humidity levels; the other major consideration is keeping condensation from occurring on interior surfaces and within structural cavities like exterior walls. Excess moisture in these areas can cause problems from peeling paint, cracking of siding, deterioration of building materials and insulation. On the home's interior, moisture can promote mildew formation and contribute to health problems.

Other disadvantages of high humidity include the growth of mould, odors becoming more noticeable, and staining when condensation occurs on windows and around nails or screws in walls and ceilings. In addition, high humidity can worsen respiratory problems for people with allergies.

An early indication of high humidity levels in home is condensation on windows. Because they are usually the coldest surface exposed to room air, they fog up first. By taking action to reduce condensation on windows, you should be able to avoid condensation problems from occurring inside the walls.

3.5.4 Interpretation & Advice

The purpose of this section is to interpret the energy costs and the environmental conditions presented previously giving useful advice for further energy saving opportunities.

The users identify the most important parameters that affect energy consumption and they are then able to take action in order to avoid energy wastage.

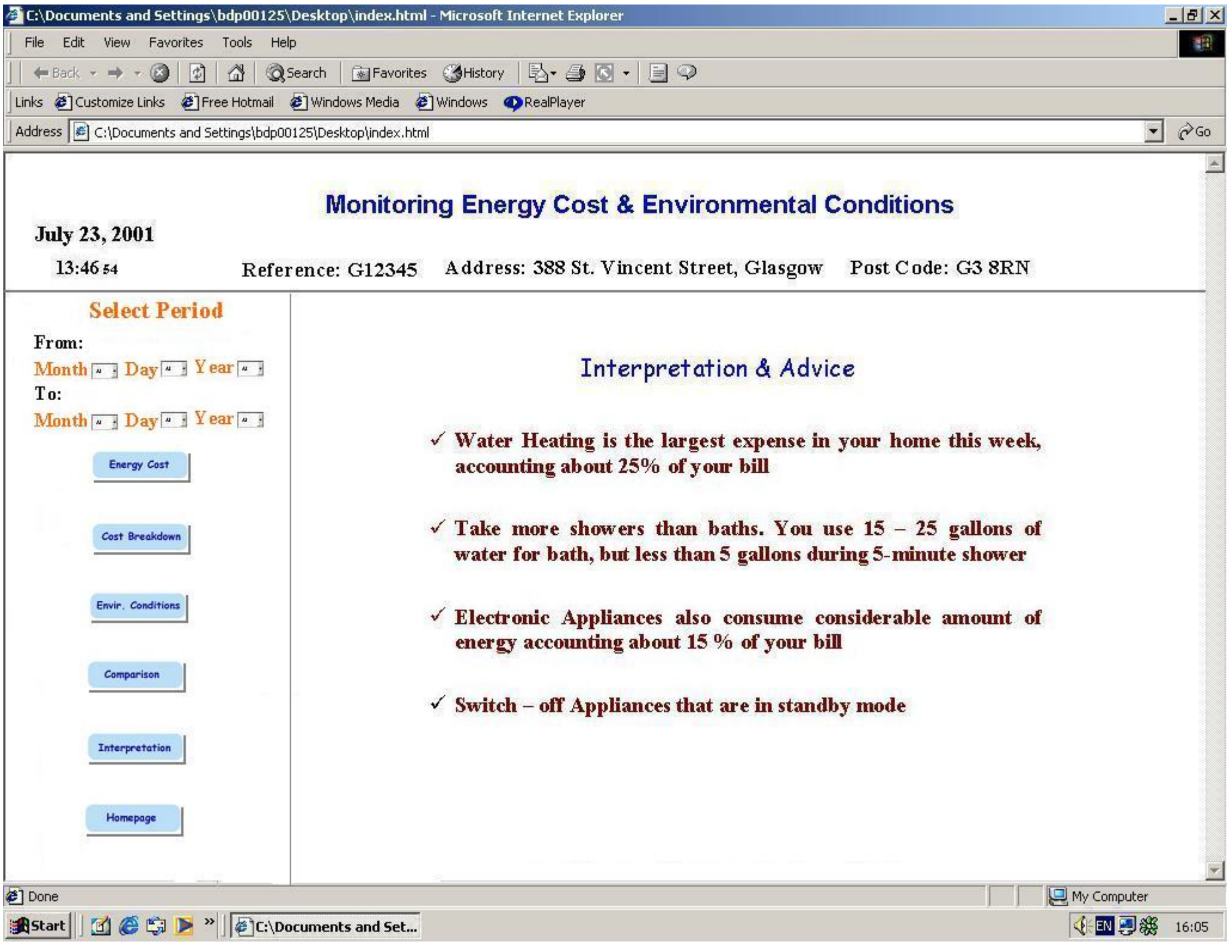

Figure 3.8 *Display for the Interpretation of energy usage*

Figure 3.8 could represent an example of energy cost analysis and provides some advices that could improve energy efficiency to the user's house and therefore save more money from the energy bills.

3.5.5 Energy Comparison

Before users can access the benefits of improving the energy efficiency of their homes, they must be able to gauge their current level of performance, in terms of fuel and electricity costs over recent periods. From these figures they can assess energy performance and more importantly, the benefits of making improvements. Comparisons can indicate the potential for improvements and can be used to show progress over time. Comparisons can also be made between homes in a group or estate. Energy use varies widely, even among seemingly identical homes. This is because of differences in a house design, appliances, lifestyles, and comfort requirements.

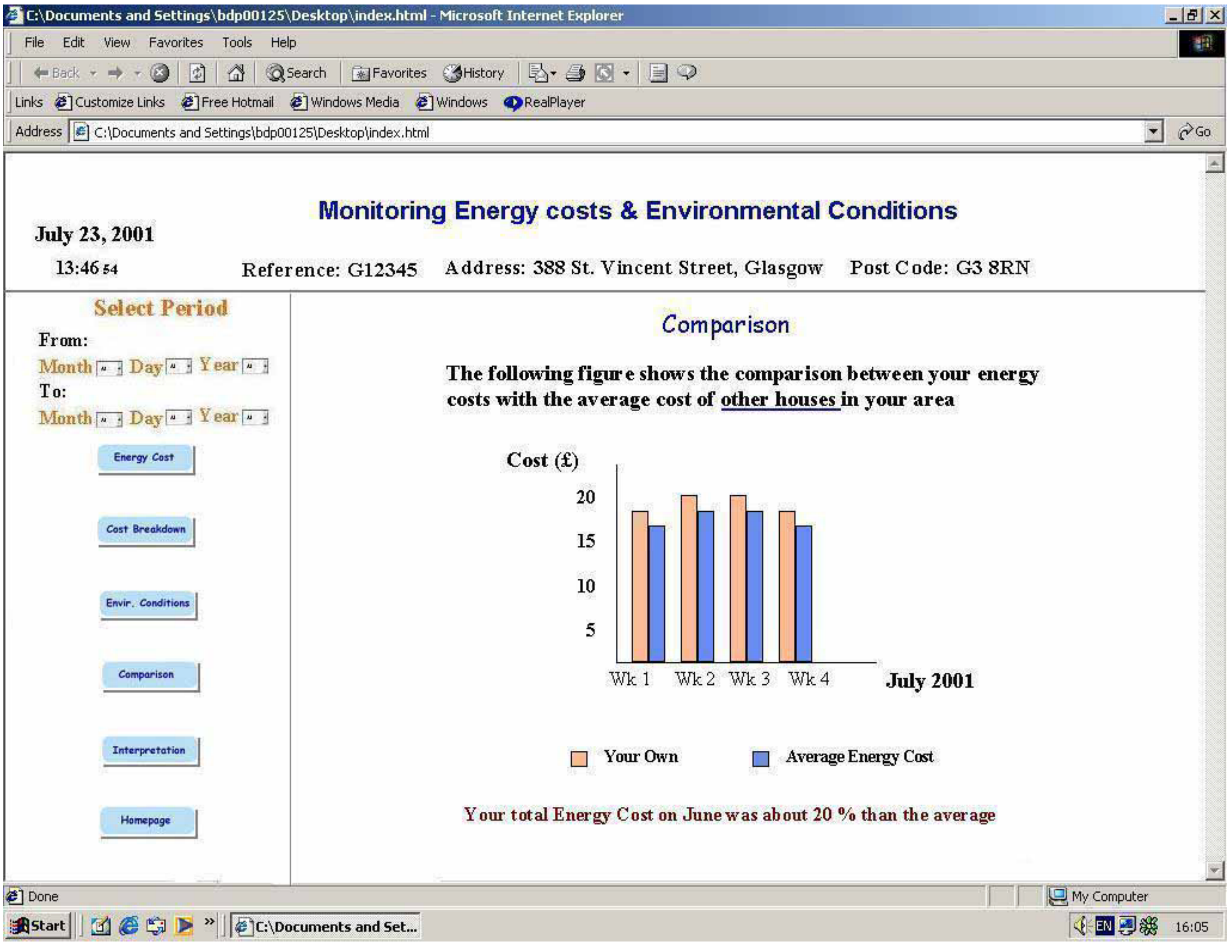

Figure 3.9 *Neighbourhood's Energy Comparison*

The user can compare his/her energy cost with the average cost of other houses in the same area. After clicking on the indicated link, a bar chart appears indicating the user's monthly energy cost against the average energy cost of houses in that area. Underneath the bar chart there are comments describing the difference between energy costs. The user can compare easily his/her energy performance with the average, helping to make decisions regarding energy saving opportunities.

3.6 Control Operation of Appliances

One of the most significant energy management services is related to the control of home appliances as this area it offers the opportunity for considerable energy cost savings.

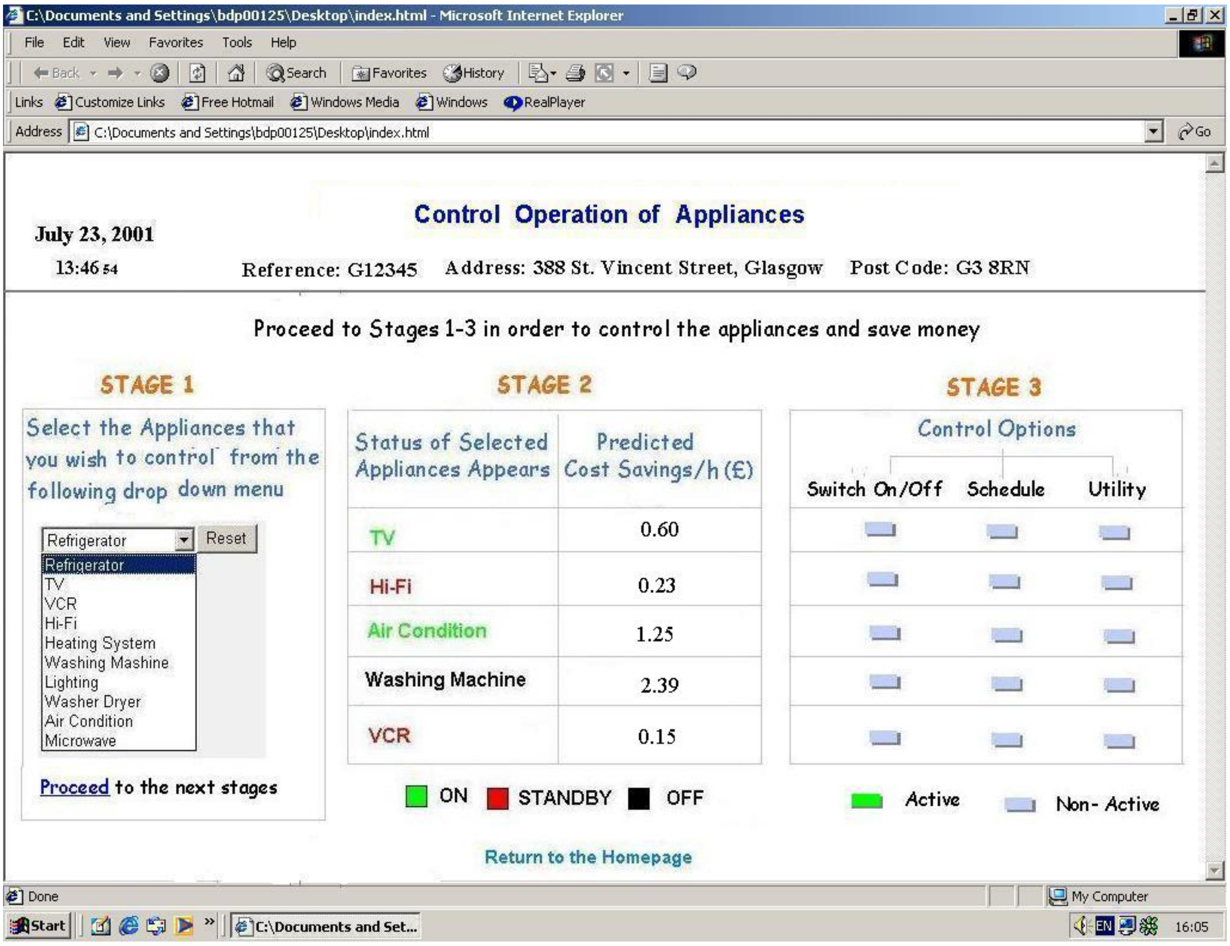

Figure 3.10 *Using the Control operation of home appliances*

Through the web page illustrated in figure 3.10, the user would be able at anytime, and from anywhere, to easily control his/her appliances in a secure environment.

The Control operation of appliances takes place in three stages because it is easier for the user to make decisions.

1) At the first stage the user is asked to select the appliances that he/she wants to control. After that, he/she clicks on the appropriate link to proceed to the next stage.

2) At the second stage the status of the selected appliances appears together with the predicted cost savings. The user can achieve these cost savings if he/she controls the appliances at the next stage.
3) The third stage is concerned with the control of the appliances. It can be implemented with one or more of the following options:
   - *Switch On/off* appliances that are in use or in standby mode.
   - *Schedule* the operation of appliances by defining the starting and finishing hours (e.g. Air Condition - Start: 15:30 Finish: 16:20).
   - Let the *Utility* make the control operations

3.6.1 Standby power usage

Separate studies indicate that standby power is responsible for 20-60W per home in developed countries. Furthermore it is responsible for about 2% of developed countries total electricity consumption and the related power generation produces almost 1% of their carbon emissions.

Standby power recently gained recognition as a unique and significant use of electricity. A recent study of videocassette recorders (VCRs) in the United States showed that more electricity is consumed while VCRs are in standby mode than while actively recording or playing. A study in New Zealand revealed that over 40% of microwave ovens consumed more electricity over the course of a year in standby mode, powering the clock and keypad, than in cooking food. Many countries have already begun programs to reduce standby power in the most prominent appliances, such as televisions (TVs), VCRs, and audio equipment.

The need to find measures to reduce CO_2 emissions has heightened interest in standby power. Standby power has several features that make it especially attractive as a CO_2 mitigation measure. First, it is technically feasible to greatly reduce standby power use without causing any reduction in features or amenities. Second, it is already cost-effective in most situations. Third, standby power use is generally similar in most developed countries and is consumed by appliances that are internationally traded. These unique characteristics make standby power an ideal candidate for international, coordinated action.

The user, through the Web site, could easily switch off appliances in standby mode from anywhere and at any time. This would have the effect of saving money without any reduction to their amenities. Another option would involve the coordination of the utility that could do the switching for them.

3.6.2 Demand side management of power

In the case where the user allows the utility to make the control operations, Demand-side management programs would be applied to their homes. Demand-side management (DSM) programs consist of planning, implementing, and monitoring activities of electric utilities which are designed to encourage consumers to modify their level and pattern of electricity usage.

In the past, the primary objective of most DSM programs was to provide cost-effective use of energy and capacity resources in order to defer the need for new sources of power, including generating facilities, power purchases, and transmission and distribution capacity additions. However, due to changes that are occurring within the industry, electric utilities are also using DSM as a way to enhance customer service. DSM refers only to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load-shape changes arising from the normal operation of the marketplace or from government-mandated energy-efficiency standards.

Electric utility DSM refers to programs implemented by utilities to modify customer load profiles. Such programs have a variety of objectives.

- **Energy-efficiency** programs reduce energy use, both during peak and off-peak periods, typically without affecting the quality of services provided. Such programs substitute technologically more advanced equipment to produce the same (or a higher) level of end-use services (e.g., lighting, heating, cooling, drive power, or building shell) with less electricity.
- **Peak load reduction** programs focus on reducing load during periods of peak power consumption on a utility's system or in selected areas of the transmission and distribution grid. This category includes interruptible load tariffs, time-of-use rates, direct load control, and other load management programs.
- **Load shape** flexibility can be achieved by programs that modify prices, cycle equipment, or interrupt service in response to specific changes in power costs or resource availability. These approaches include real-time pricing and time-of-use rates for pricing periods that have flexible hours. They may also include interruptible load tariffs, direct load control, and other load management programs when those activities are not limited to peak load periods.
- **Load building programs** are designed to increase use of electrical equipment or shift electricity consumption from peak to off-peak hours thereby increasing total electricity sales. This category includes valley filling programs that increase load during off-peak periods and programs that introduce new electric technologies and processes.

3.7 Information Service

The purpose of this section is to provide help and advice for the creation of a more energy efficient home. The Web Page as illustrated in figure 3.11 makes available news/energy efficiency tips, an on-line forum, an expert advice section and feedback information.

The news part relates to energy products and services that are available in the market, tariffs/discounts offered by different suppliers helping the user to make decisions. The energy efficiency tips are usually based on statistical studies, and keep the user aware as to how he/she can achieve energy savings.

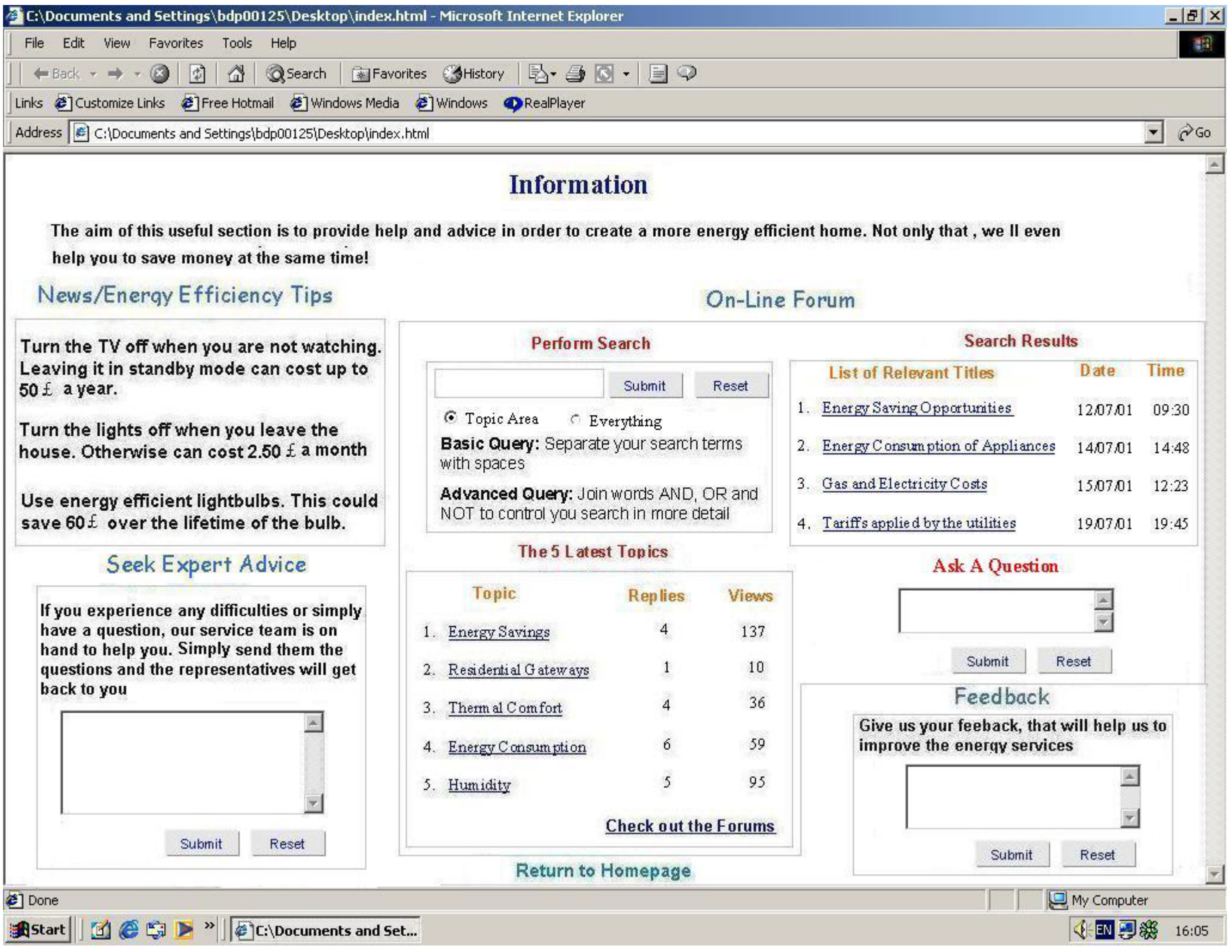

Figure 3.11 *A display of the Information Web Page*

The user has also the opportunity to use a dynamic knowledge exchange via the on-line forum. The users with a common interest or profession to meet with experienced peers and exchange services and information related to their field. The challenge is to encourage free expression and keep focused on the task at hand. Users can post messages, brainstorm, and review documents for any kind of topic relating to residential energy services.

Whether the user is looking for a quick solution or an answer to a question, he/she can narrow the search with fields for a keyword or phrase, a specific topic, a question's status, specific dates, and the amount of question points offered. After that, search results appear with the relevant topic titles. Moreover, the 5 latest topics independent of the search are listed by a date order. The form appears in a question-answer format and at the end a field is available to the user for any comments. The user can also quickly access, sort and search all questions ever asked, from an available database.

The user is able to seek expert advice should any difficulties be experienced or should he/she have a question about the service. a question about the service. Finally, the user is asked to submit a feedback form. The information is being used for service improvement purposes.

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This chapter relates to the technical perspective required for the real implementation of the web site presented previously. There is also analysis on the necessary data capture requirements to allow the display information to appear on the web pages.

4.1 Sensor technology

Homes would be provided with sensors for measuring a range of parameters including energy use, environmental conditions, etc. The software for handling the raw data from the sensors would be installed in the gateway. The preprocessed data would be communicated to the Service Provider. After that a data base system for analysis of data and presentation of results would be linked to this Service Provider. The following sections deal with a description of sensor technology for power consumption, air temperature, humidity and CO_2 measurements.

4.1.1 Electrical Energy Measurement

Principle

Sensors and instruments designed for energy measurements are available in a variety of configurations and capabilities. These types of instruments typically sense the values of applied voltage and current take into account elapsed time of usage then multiply the quantities together resulting in a measure of the amount of power consumed.

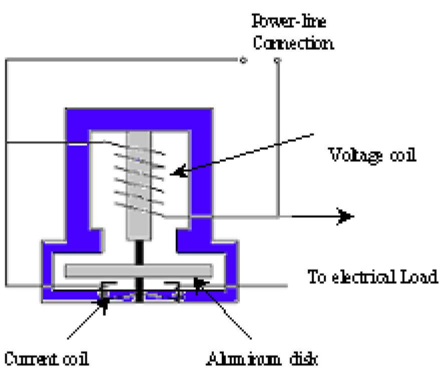

Figure 4.1 *KWh meter*

A voltage-sensing coil connects across the incoming power line is used to monitor the applied line voltage. Similarly, an independent current-sensing coil is connected in series with one side of the power line to monitor current values. Both of these coils are mounted inside the meter enclosure and attached to a metal frame as shown in figure 4.1. Voltage and current values produced by the power system cause an electromagnetic field to appear around each coil. This causes an aluminum disk to rotate like a motor. The rotational speed of the disk is related directly to the amount of power consumption. A gear train driven by the disk shaft turns the dial mechanism. Power consumption recorded is thus recorded.

Sensor Positioning

The vast majority of the new technology sensors can be easily installed and very often only require to be plugged into a standard electrical outlet.

4.1.2 Temperature measurement

Types of Sensors

Temperature is one of the most common and most important measurements that we make in the evaluation of home equipment today. Precise control of temperature is a key factor in the operation of nearly any home.

Electronic temperature measuring instruments are unique when compared with non-electrical measuring equipment. First, electrical energy must be supplied to the instrument by an external source in order for it to become operational. Second, it must employ a special instrument, known as a *transducer*, to change temperature variations into electrical signals.

There are three basic types of temperature sensors commonly used today: Thermistors, Thermocouples, and Platinum RTDs (Resistance Temperature Sensors). In general, thermocouples provide the most economical means of measurement over the widest temperature ranges. Thermistors and platinum RTDs, will, in general, provide a more accurate means of absolute temperature measurement. This is particularly true over narrow temperature ranges.

Thermistors

Thermistors are very small solid-state devices that are used in instruments to detect changes in temperature. The solid-state designation associated with a thermistor implies that it is made of a semi conductive material. Fabrication is achieved by mixing together such things as manganese, cobalt, and nickel oxides. Thermistors are made in the shape of beads, rods, washers, and various other configurations. For temperature instruments, the thermistor is placed into a variety of probe structures. A distinguishing feature of the thermistor is its classification as a negative-temperature-coefficient device. This characteristic refers to its ability to change resistance in a direction that is opposite to that of the temperature being sensed. An increase in temperature causes a decrease in thermistor resistance, whereas a decrease in temperature causes an increase in resistance.

Thermocouples

Thermocouple instruments respond to a rather simple and versatile principle based on the generation of electricity by heat. When two dissimilar metals wires are joined together at a common point and subjected to heat, a dc voltage is produced at the free ends of the wire. The resulting voltage measured across the two wires can be used to indicate the temperature applied to the measuring junction.

RTDs (Resistance Temperature Detectors)

Resistance temperature instrument operation is based on the property of certain metals to change resistance when subjected to heat. The sensing element of this instrument in simply a long piece of wire formed into a coil and wound around a ceramic core. The entire assembly is then enclosed in a protective metal sheath. Electrical connection is made to the wire coil by terminals or extension wires. Temperature changes developed by the RTD element are obtained by connecting it to a Wheatstone bridge circuit. In order for a specific temperature to be determined using the bridge circuit, the resistance of the RTD must first be determined.

When the resistance value of the RTD is decided, the temperature can be determined by locating this value on a resistance-temperature graph. Platinum wire, for example, offers 10 ohms of resistance at 0 °C. An increase in temperature to 100 °C will cause a linear rise in resistance to 13.8 ohms. Temperature can therefore be determined by measured changes in the resistance of the RTD element.

Sensor Positioning

Optimum positioning of sensors can be a complex matter as it can depend upon the design of the house. It is an issue that often leads to conflict between architects and engineers. The problem is that if the space temperature is not measured, or cannot be estimated accurately enough from other measurements, then it cannot be controlled satisfactorily by automatic means. The temperature of the air extracted from the occupied space is often used as a measure of the space temperature. Difficulties arise if the radiant temperatures within the spaces do not track the air temperature, or if the air is extracted through the luminaires. If the light output of the luminaires is varied by a lighting control system then the amount of heat picked up by the extracted air will vary, leading to a difference in temperature between the room air and the extracted air. In principle these effects can be

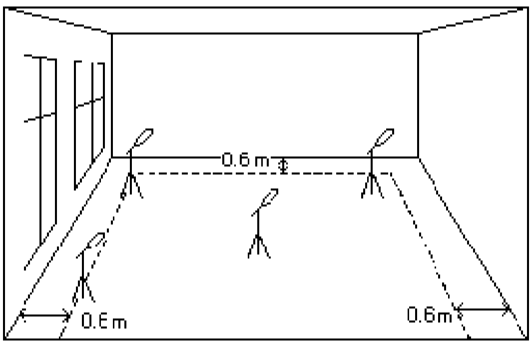

Figure 4.2 *Example of Sensors arrangement*

corrected by a modern control system but careful commissioning is required to obtain satisfactory performance.[1]

Temperature sensors should be positioned such that they are not unduly influenced by direct heat gains or draughts whilst allowing free air circulation. Ideally, the sensors should be positioned at the user's centre of gravity. However the user's centre of gravity varies between sitting and standing persons. We can therefore comprise and put sensors at different positions dependant upon the layout of the living space. In rooms where the living spaces are not easily identified the measurement point should be placed at least 0.6 m away from walls or fixed heating or air-conditioning equipment as illustrated in figure 4.2. Good practice dictates that the sensor positions chosen should range from the coldest to the warmest, with one in the exact centre of the room.

4.1.3 Humidity Measurement

Principle

A number of very specialized moisture sensors are used with electronic hygrometers to measure the moisture content of air. These sensors are designed to react to different levels of moisture by causing a physical change in some electrical property. For the most part, sensors of this type are rugged, compact, and can provide remote readout capabilities that cannot be achieved by other RH (Relative Humidity) instruments. RH probes are made of an insulating material that is interleaved with a grid like structure. The grid is coated with a hygroscopic material such as lithium chloride. Hygroscopic materials have the inherent ability to absorb and release moisture. Moisture absorbed by the sensor causes a decided change in its electrical resistance. This electrical change, when used in one leg of a Wheatstone bridge, will produce an imbalance, resulting in a flow of current. Variations in bridge current are then used to indicate relative humidity values.

Sensor Positioning

The hygrometer will show the relative humidity (RH) in the home. The RH will not be exactly the same throughout the home. The hygrometer should not be placed near a radiator, a heat register or a chimney, or in any other location where it could be affected by direct heat. Usually the hygrometer does not produce instant results and it may take up to two hours to provide a stable reading or to adjust to sudden changes in relative humidity.

Accuracy

The hygrometer provides accurate readings subject to careful use and calibration. All hygrometers should be calibrated on a regular basis. Some are not properly set when they leave the factory. Others, even the best models on the market, may experience what is known as drift, which means that they do not hold their accuracy over long periods and need to be regularly re-calibrated. Once the user has calibrated his/her hygrometer he/she can be confident that accurate readings are obtained.

4.1.4 CO_2 measurement

Principle

Changing variables result in a wide range of sensor designs. Gas sensors based on semi - conducting metal oxides are simple yet robust. The metal oxide is prepared in the form of a thin film on a substrate, which ensures close contact between the detector material and the gas phase. The electrical resistance of the gas-sensitive thin film is measured using electrodes prepared from precious metals. An electrical heater heats this chip to its operating temperature in the range of several hundreds of degrees, at which point a chemical reaction between the gas and the metal oxide changes its electrical conductivity. The measured resistance of the oxide film is a function of the temperature and gas concentration. For a constant temperature, the function can be determined inversely and under favourable conditions, the gas concentration can be determined. Although the physical layout of a metal - oxide gas sensor can be easily described, the chemistry of the reactions between the metal - oxide and the gas phase is highly complex.

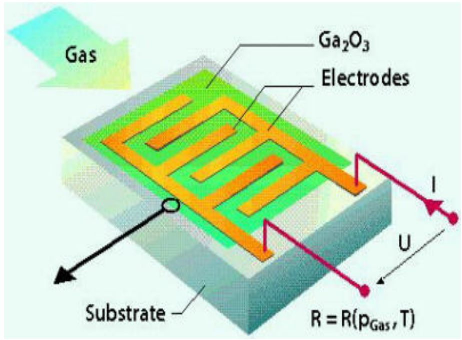

Figure 4.3 *A typical gas sensor*

More specifically, CO_2 concentrations are calculated by measuring the absorption of infrared light (at a wavelength of 4.26 microns) by CO_2 molecules. As CO_2 levels rise, more infrared light is absorbed. CO_2 sensors incorporate a special source of infrared radiation, a detector, and electronics to detect the absorption. This method of measuring CO_2 levels is called non-dispersive infrared (NDIR).

4.2 Database Design Approach

There is an involved process associated with analyzing the web site requirements and the environmental demands. A suitable database model should accurately reflect the web site's functionality in the real world. The implementation of such a model requires an appropriate methodology.

A basic assumption behind the systems analysis life-cycle approach is that systems will eventually become obsolete and have to be replaced. In the database environment there is reason to question this assumption. The database can be designed in such a way that it can evolve, changing to meet future information needs of the Energy Service. This evolution is possible with the development of a true

logical model of the system. A well-designed database model protects the data resource by allowing it to evolve so that it serves both today's and tomorrow's needs.
The staged database design approach is a top down method that begins with general statements of needs and progresses to more and more detailed consideration of problems. The major design stages are:

1. ***Analysis of the user's environment:*** The first step in designing a database is to determine the current user environment. This step has been covered already in the Web site development presented in chapter 3.
2. *Development of a logical data model:* Using the model of the user environment, the next stage is the development of a detailed logical database model, identifying the entities, attributes, and relationships that should be represented. The types of applications and transactions, the kinds of access, the frequency of access, and other quantitative data must be specified. The result of this phase is a set of database specifications. This stage is going to be analysed in this chapter.
3. *Selection of a database management system.*
4. *Mapping of the logical model to the database management system*
5. *Development of the physical model:* Layout of the data taking into consideration the structures supported by the chosen database management system and hardware and software resources available.
6. *Evaluation of the physical model:* It may be helpful to develop a **prototype**, implementing a selected portion of the database so that the user views can be validated and the performance measured more accurately.
7. *Perform fine-tuning if indicated by the evaluation*: Adjustments such as modifying physical structures or optimising software can be done to improve performance.
8. *Implementation of the physical model:* If the evaluation is positive, the physical design can be implemented and the database would become operational.

4.3 Data Modelling

The functional specification of a system can be defined through the analysis of collected data. This functional specification is recorded in a formal document. This formal document defines exactly the capabilities of the system, the type of data that the system processes, how the data is actually processed and lastly, the inter-relationships between data elements. System requirements are usually specified with the aid of assorted charting techniques, such as data flow diagrams, coupled with a natural or structured description of the details of the functional components, as might be recorded in a data dictionary (data dictionary is repository of information that describes the logical structure of the database).

4.3.1 Data flow diagrams

When examining an existing Information System and its associated information requirements, it is important to recognise some key concepts:

- What the data comprises of
- Where the data comes from
- How the data passes from one point to another in the system.

The use of the data flow diagram is a useful analysis tool.

The Data flow diagrams show the flow of data through the system. They provide a useful model for communicating with users, other designers, and managers about the present system and the proposed system. Figure 4.4 shows the basic symbols employed in constructing

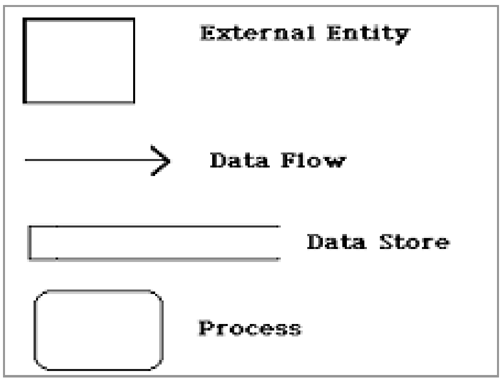

Figure 4.4 *Basic notations of the Data Flow Diagrams*

data flow diagrams. Note that in this context the word “entity” means any person, other system, or organization that supplies data to or receives data from the system.

4.3.2 Authentication

Firstly, an existing user would request authentication in order to proceed to his/her personal web site. For that purpose a unique *user ID* and a *password* is required. The user ID and the password would be given to the users that have already been registered.

The New User would be requested to enter descriptive details of the entity. The decision support software would then register the new entity under a specified reference number. Typical descriptive details refer to: User’s *name*, *address*, *postcode*, *telephone number and any other contact information.*

Once the descriptive details of the new entity are stored, the user would need to enter the associated energy details. Additional information regarding the fuel type, the number of buildings included in the entity, the meter identities and a list of the *appliances* that the user wants to add to this service are also requested.

For the Authentication process we have the following data flow diagram:

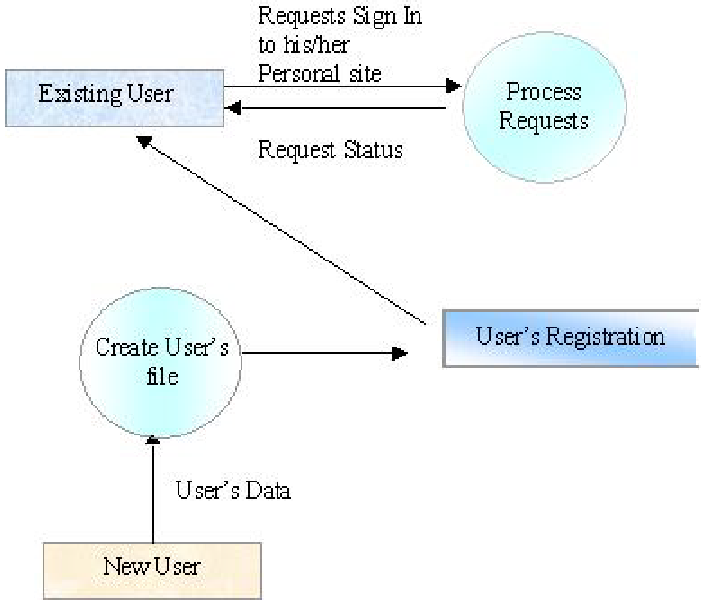

Figure 4.5 *Data flow diagram for Authentication*

The data store used would relate to the user's registration details.

- An existing user would first type his/her user ID and password and then requests access to the service.
- The system would then process the request by checking his/her identification details from the data store.
- A new user would first need to send his/her personal details to the system. After that, a file would be created by the system and stored in the database. The system would send a user ID, password and a reference number to the user.

For the web page (see chapter 3, page 30) relating to the energy services only, the user's *reference number*, the current *date* and *time* would be required. This page would be the same for all users, as it would contain any personal information and serves as a link page between the start up page and the provided services.

4.3.3 Load Integration

Data required

For the Energy cost display information, which is expressed in pounds (£), the data would originate from the user's home appliances. Two factors determine how much energy an appliance will use:

1. The amount of power it takes to operate the appliance.
2. The number of hours that it runs.

To calculate the amount of energy it takes to operate the appliance, simply multiply the nameplate wattage by the number of hours it runs. Again we need the entity's *reference number*, *date, and time*. Additional requirements are the power consumption (W) of appliances, the number of operating *hours* and the *tariff* applied by the energy supplier. For gas costs we need the consumption (cubic feet/h) multiplied by the appropriate tariff. Furthermore we would need to know the tariffs applied by the supplier according to the day- night- weekend rates and the associated discounts. The *comment* could be done either *manually* or automatically according to a well-specified *algorithm*.

For the web page associated to the energy cost breakdown, it is necessary to have the following information:

- ✓ The user reference number, date and time.
- ✓ A list of appliances in use.
- ✓ Each appliance's power rating, the periods of operation and the tariffs in operation.

The data flow diagram of the system illustrated in figure 4.3.The only difference is that the total energy cost breakdown is expressed in more detail. The pie chart, which represents the percentage cost of the major appliances, comes from the formula: $\frac{Appliance'sEnergyCost}{TotalEnergy\cos t} \times 100\%$.

For the interpretation and advice of energy consumption patterns the following data is essential:

- ✓ Reference
- ✓ Date
- ✓ Time
- ✓ Total Energy Cost (£)
- ✓ Energy Cost (£)/ Appliance
- ✓ Air Temperature (°C)/Room
- ✓ Humidity (%)/Room
- ✓ CO_2 (ppm)/Room

The analysis of the results could be done manually or automatically utilizing an algorithm, which would take into consideration the energy consumption data. In this case the data flow diagram would be equivalent to the energy cost diagram shown in figure 4.6 (in combination with the prevailing environmental conditions).

Energy cost comparisons (mentioned in the previous chapter) could be undertaken, comparing data from the user's home to data from other similar houses in the same postcode area. For this purpose, the following data would be required:

- ✓ Reference
- ✓ Date
- ✓ Time
- ✓ Energy Consumption (user's house)
- ✓ Number of houses
- ✓ Location
- ✓ Energy consumption/house
- ✓ Tariffs

Data flow diagrams

For energy cost requests over a specified period of time, the following data flow diagram was developed:

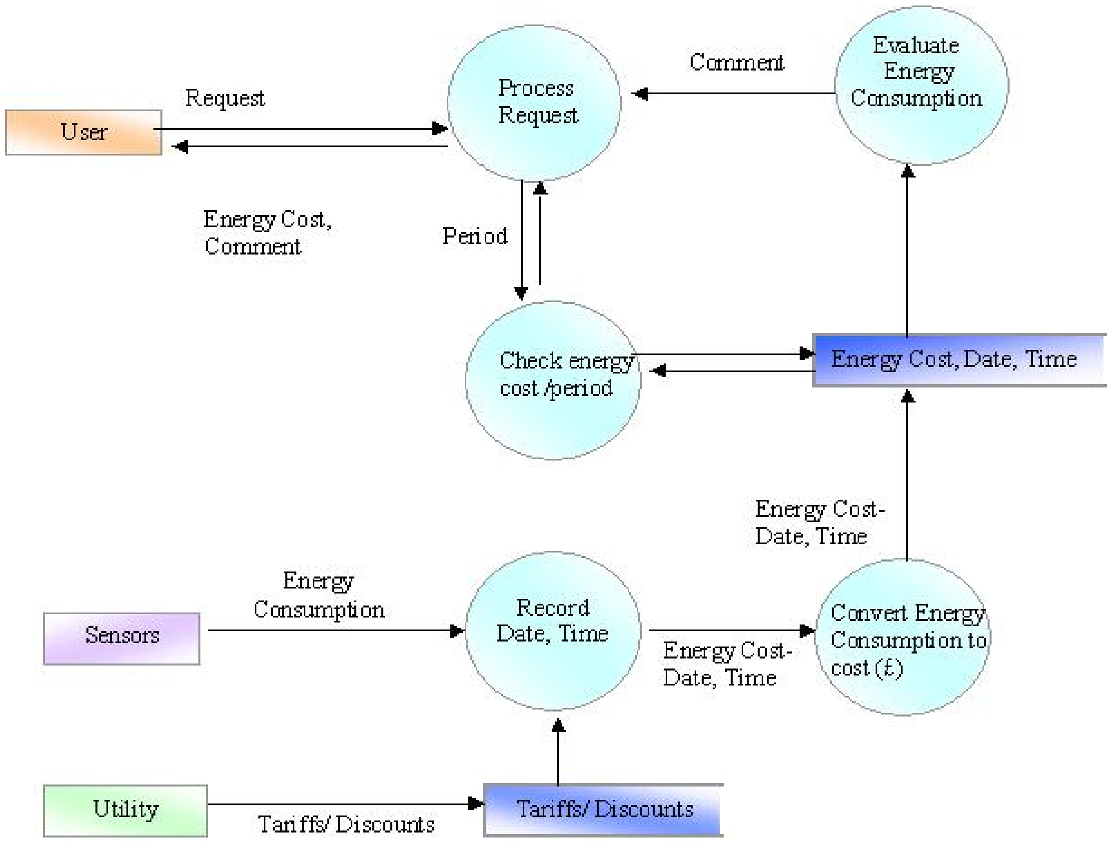

Figure 4.6 *Data flow diagram for energy cost*

There are three entities: the user, utility and the sensors. In the case of the user the following data flow would exist:

1. User requests energy cost on specified period.
2. Request processed by the system.
3. The system picks the energy cost at the required period from the data store.
4. At the same time another process picks the data from the data store and make evaluation about the energy consumption.
5. Finally the user receives energy cost and comments.

The flow of data originated by the sensors would be as follows:

1. Sensors capture the data from the home appliances and send it to the system.
2. At the same time the date and time are recorded by the system
3. The energy consumption is converted to energy cost according to the tariff applied to that period (obtained by the utility).
4. The data is then stored in the database.

The data flow diagram for comparison purposes is illustrated by figure 4.7.

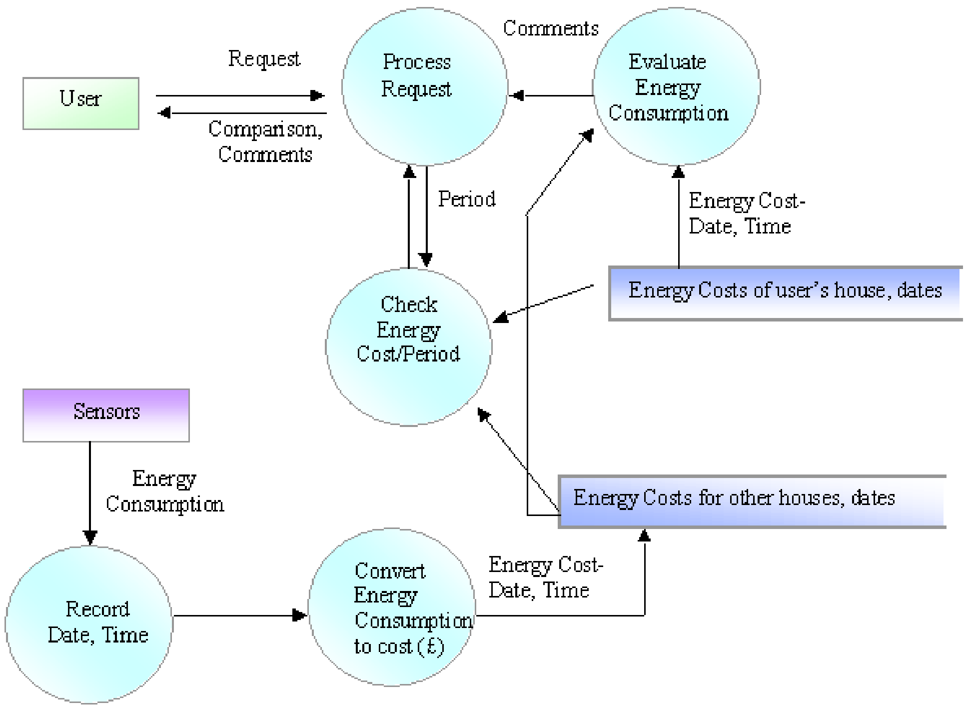

Figure 4.7 *Data flow diagram for energy cost comparison*

In the case of fig. 4.7 we have two main entities: the user and the sensors. For the user the data flow would be as follows:

1. User requests comparison at specified date, between his/her energy cost against the average energy cost of other houses in the same area.
2. The required energy costs are obtained by the databases and directed back to the user with comments.

For the data originated by the sensors, the flow would take place in the following steps:

1. Sensors from all the connected houses of the area capture the data from the home appliances and send it to the system.
3. At the same time the date and time are recorded by the system
4. The energy consumptions are converted to energy cost according to the tariffs applied to that period by the utilities.
5. The data is then stored in the database.

4.3.4 Emissions

Data required

The Web Page relating to the environmental conditions (as shown in Chapter 3, page 37) would again require the *reference number*, *date* and *time*. A *list of the rooms*, with an analysis of environmental conditions, would also be required.
In addition maximum and minimum air temperature (°C) (to obtain the mean value), the relative humidity (%) and the carbon dioxide concentrations expressed in parts per million (ppm) would be required. The "*safe environment*", "*risk to health*" *and "dangerous for health" levels* for all of the above properties, would have to be stored on the database.
Comments would depend on the measured values and the standard levels stored on the database. These would be implemented manually or by the development of an algorithm.

Data flow diagram

The Data flow diagram of the system is illustrated in figure 4.8.

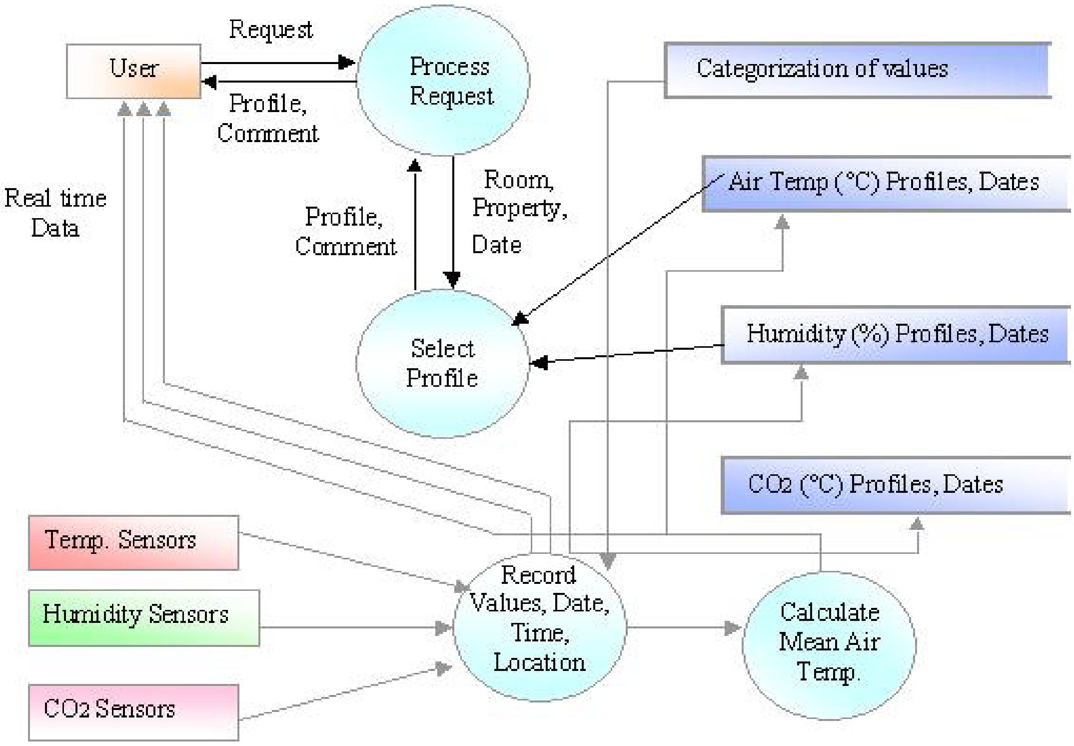

Figure 4.8 *Data flow diagram for Environmental conditions*

In the case of fig.4.8 we have four entities: the user, temperature sensors, humidity sensors and CO_2 sensors. When the user requests a property profile (temp/humidity/CO_2) the following steps would take place:

1. User request property profile, at specific location and date
2. The request sends the details to another process for selection of the required profiles.
3. Profiles selected by the data stores are then directed to the user.

The data flow, which originates from the sensors and is processed down the chain to the user. There exist the following main steps:

1. Sensors capture the data from each room and send it to the system

2. The system records the received values, date and time together with the originating location. At the same time categorization of the values takes place. This data is then directed to the user and the data stores.
3. For the Air temperature values, another process calculates the mean values and then these are then directed to the user and the data store.

4.3.5 Control Operations

Data required

The Web page relating to the control of the operation of home appliances would require the following data:

- ✓ Reference
- ✓ Date
- ✓ Time
- ✓ List of appliances
- ✓ Status of appliances
- ✓ Power (watts)
- ✓ Tariffs

Detection system for appliances not being shut off

Old people can be forgetful and may forget to shut off energy-using devices like lamps, irons, cooking plates, heaters etc. This cannot only be dangerous (safety: fire protection) but also energy wasting. A system capable of giving a warning when appliances are left on at times where these appliances would normally be shut off could be developed. E.g. when people leave the house or go to bed. The system could also be engineered to shut down appliances automatically.

Intelligent refrigerator/freezer

An intelligent fridge/freezer would give a warning in the following situations:

- Should the door remain open as be left ajar beyond a pre set time.
- Should the interior temperature drift from a set point. This would be particularly critical as any rise in the interior cabinet temperature carries a risk of food spoiling and associated dangers of food poisoning.
- Power failure (ditto to above).

Data flow diagram

The Data flow diagram relating to the control part is illustrated by figure 4.9.

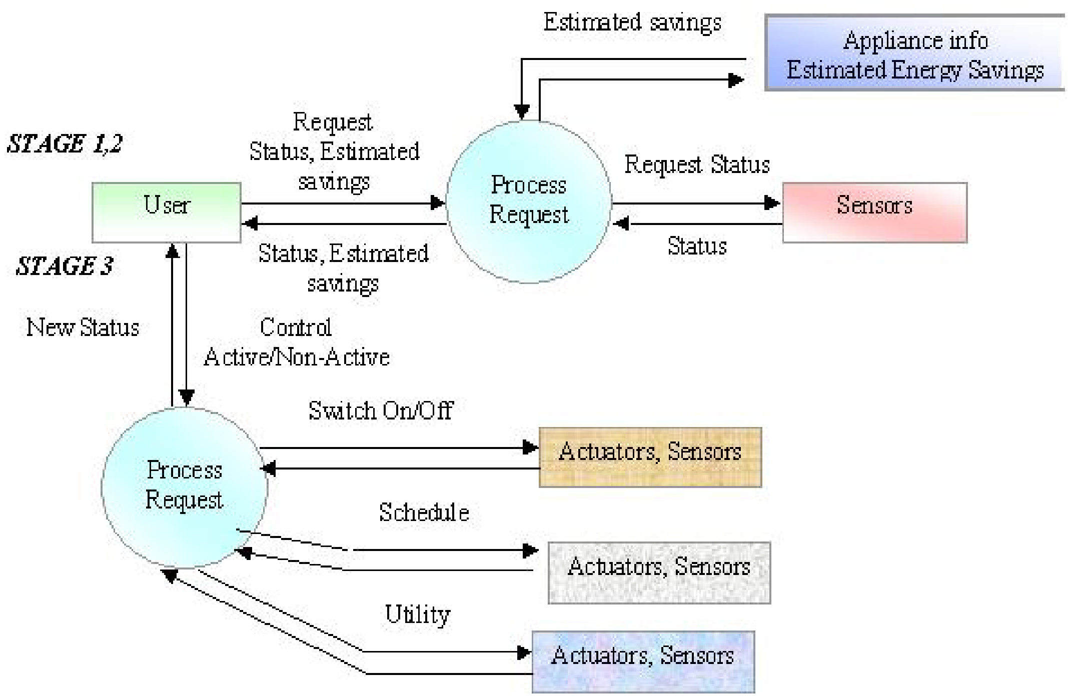

Figure 4.9 *Data flow diagram for control operation of appliances*

The control operations would be carried out in three stages, involving selection of the appliances, status and predicted energy savings. For the first two stages we have the following procedure:

1. User selects his/her appliances as candidates for supervisory control.
2. The request is processed and the sensors send the status of the appliances.
3. At the same time the estimated energy savings for the selected appliances are processed.
4. Finally the status and energy savings of the appliances are directed to the user, completing the second stage.

For the last stage, where the user implements the control, we have the following steps:

1. User selects one of the three available control options
2. The system processes the request and sends the appropriate command to the sensors and actuators. In the third case, where the utility has been selected by the user to perform the control, the command is sent there.
3. Control operation of the appliances takes place and the new status is indicated to the user.

References:

[1] Susan Roaf & Mary Hancock, Energy Efficient building, Blackwell Scientific Publications, Copywrite © 1992

[2] Anton F P van Putten, Electronic measurement systems, theory and practice, Eindhoven and Middlesex Universities, IOP Publishing Ltd © Copywrite1996

[3] Jennifer Rowley, "Designing Public Access Systems", MPG Books Ltd, Great Britain, Copywrite © 1998

[4] Catherine Ricardo, "Database systems: Principles, Design & Implementation", MacMillan Publishing Company, United States of America, Copywrite © 1990

5.1 Conclusions

"Smart" information technology for new applications and Services in homes is developing at breathtaking speed. Indeed, some technologies are close to maturity. A major issue however, one that must be understood, is that of the end user's requirements. How end users are likely to adopt such technology is a matter that must be taken seriously. "Smart" information technology is ahead of the market at the present time. New ideas and applications require informed communications and debate.

There is a clear need for real-life application trials that focus on how end users (customers) interact with new and evolving forms of information and communications technology. Further knowledge dissemination and promotion activities are called for, to enable enterprises and their customer bases to form a sharper vision of the future and take on board the many advantages offered.

These activities can benefit from the fact that the information technology within the energy field is widely seen as attractive, (witness the high visibility and free publicity concerning the "smart home"). A crucial issue in identifying, designing and implementing these kinds of services is that of the customer's acceptance of the new technology.

For the household market, price is the most important consideration. However, a broad customer interest in and support of energy saving activities and services is evident from market surveys.

The main goal of this work was to define the specifications of a new internet-based energy management service, relating to the remote control and monitoring of energy consumption in the residential sector. The first approach was to design the user interface and the second to develop the underlying data model. A number of conclusions were then drawn:

Energy services must be framed in an attractive way in order to appeal to a wide variety of customers and to fulfil their needs. From the user's perspective, the interface should be easy to use and it should be designed with typical user requirements in mind.

The energy cost information is displayed in pounds (£) and the breakdown of energy usage in percentages (%), figures easily understandable by most people. To control energy consumption and costs, regular and reliable records of energy use should be maintained. Energy costs are displayed with the aid of various charts, which are the result of the chosen monitoring period, making for more effective analysis. In such a way the users have the opportunity to identify and eliminate energy waste. Controlling the operation of home appliances through the Internet is an option that will help users to achieve money and energy savings, while also contributing to the reduction of the greenhouse gas emissions.

From a technological perspective, the specifications were developed by the collection and the subsequent analysis of the data requirements. Data flow diagrams were developed to identify <u>what</u> data is required, <u>where</u> that data is captured and <u>where</u> it is processed, contributing to a real implementation of service scenario.

5.2 Future work

Following analysis of the user's environment and the development of the logical data model of the system, the subsequent steps progress to increasingly detailed consideration of problems.

The selection of a database management system must be undertaken as a matter of importance. The designer should attempt to choose a system that best satisfies the specifications for the environment, within the constraints given.

The designer should then map the logical model to the data structures available from the chosen database management system.
It may then be helpful to develop a *prototype*, implementing a selected portion of the database so that the user views can be validated and the performance measured more accurately. Adjustments such as modifying physical structures or optimising software can be done to improve performance.

Finally, if evaluation is found to be positive then the physical design would be implemented and the database become operational.

Appendix A 1

A closer look at standards and emergent technologies for smart houses

The following figure give an overview and a context of emerging standards of importance to the networked smart home.

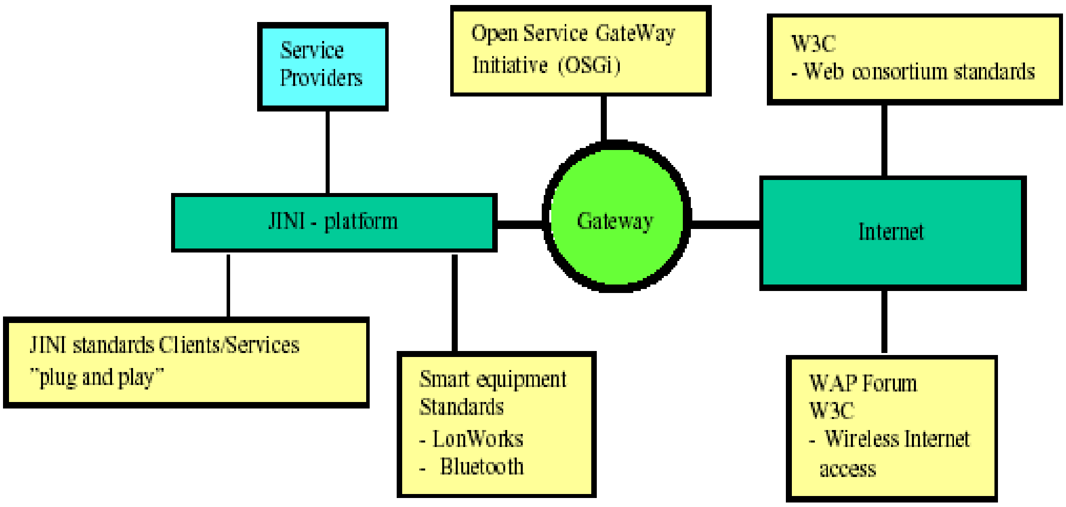

Figure A1.1 *The most important standardization efforts and technologies supporting the networked smart house*

Web Pages

Energy Cost

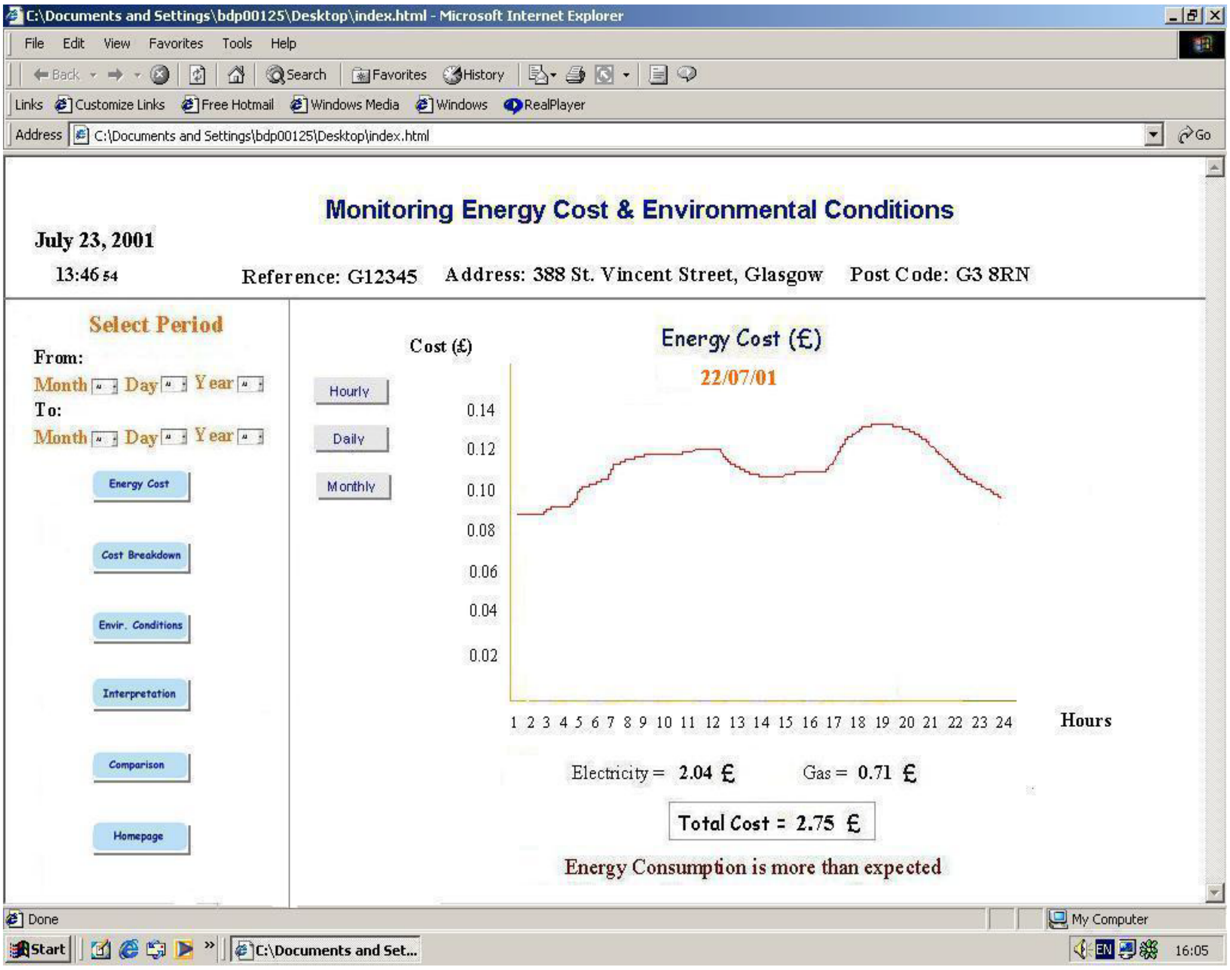

Figure A2.1 *An example of the hourly energy cost*

Energy Cost

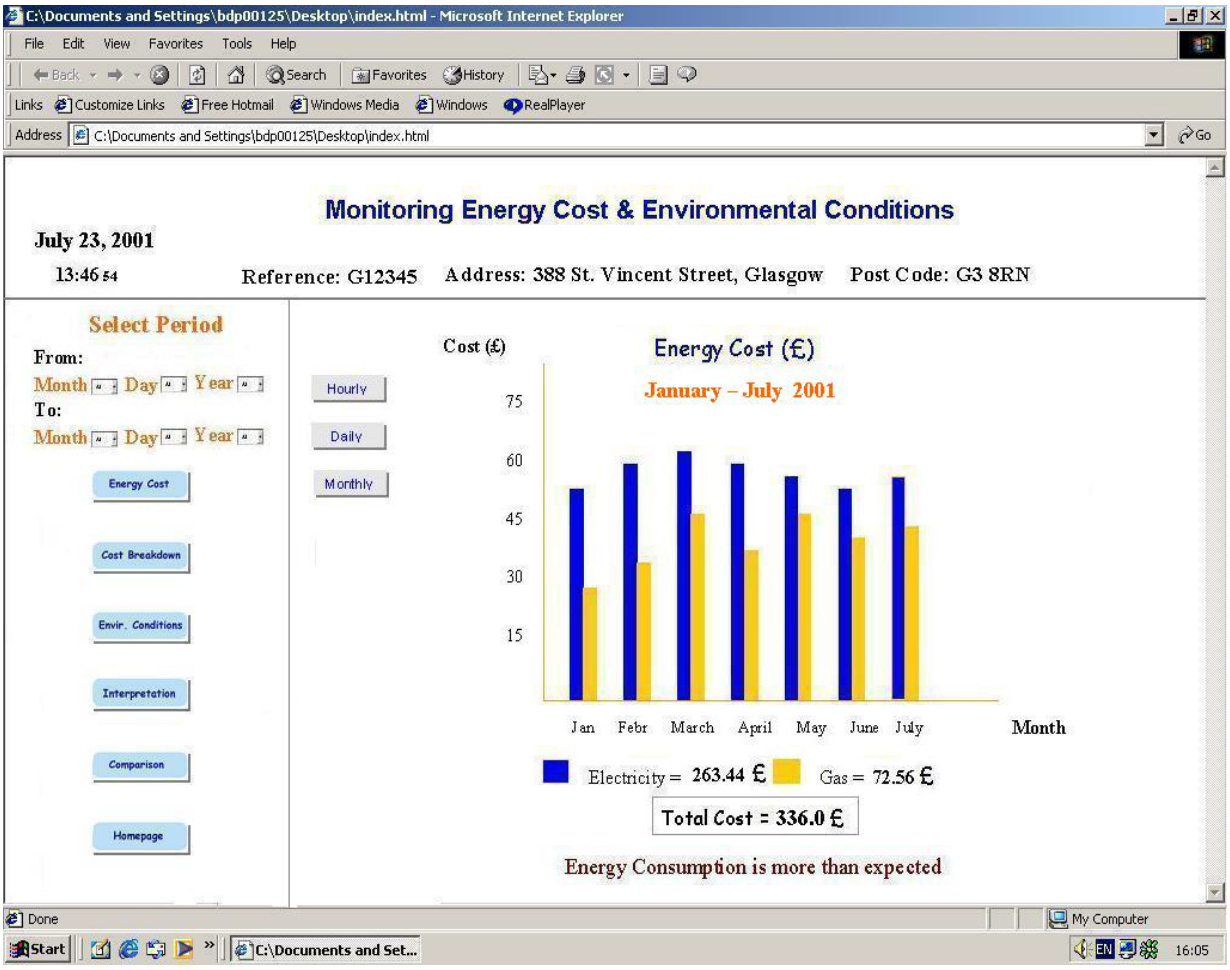

Figure A2.2 *Display of the Monthly Energy Cost*

Appendix A 2

Information

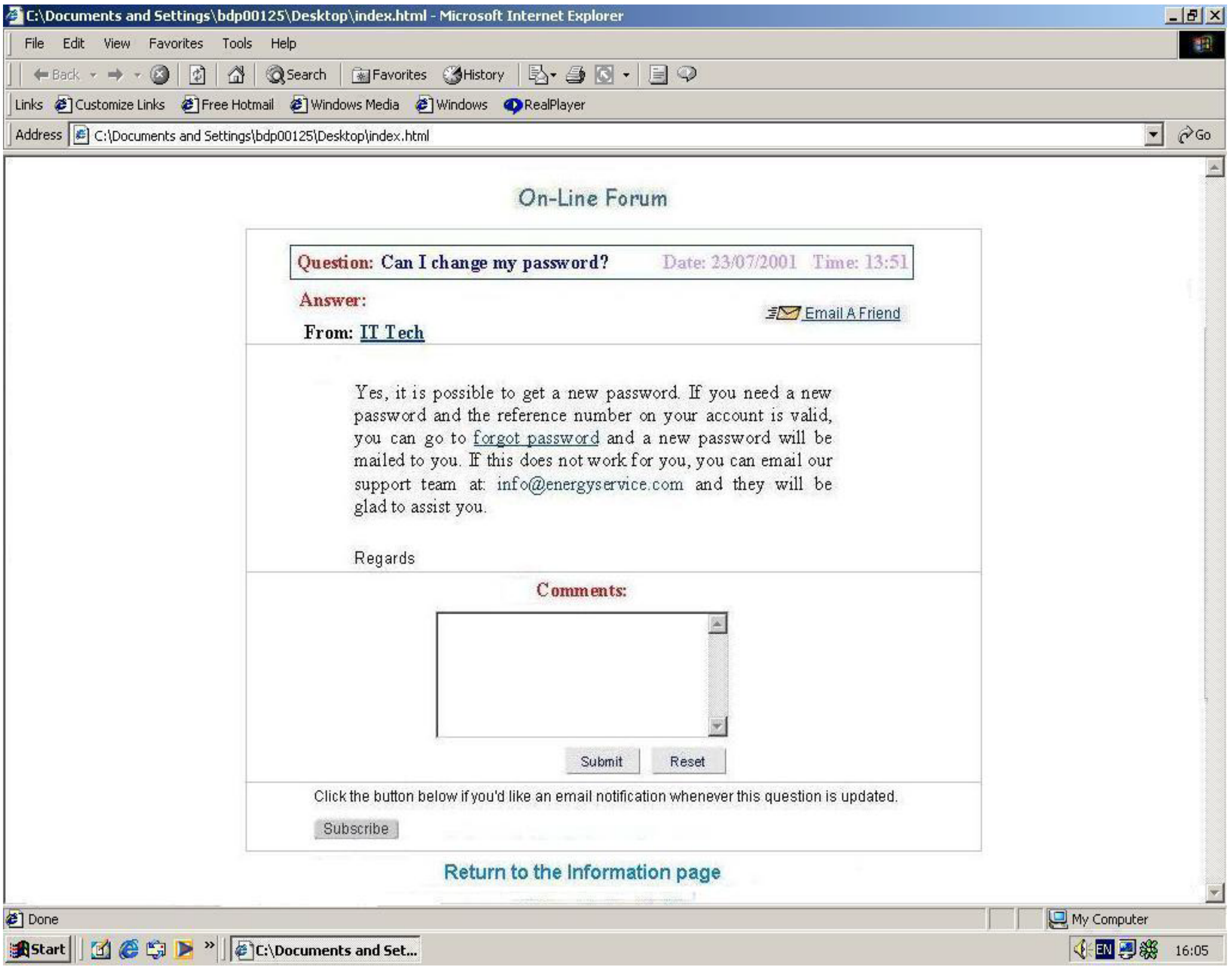

Figure A3 *Display of the On-Line Forum (questions-answers and comments)*