Online Environment & Energy Information Services: Prototype e-Services for Residents and Utilities

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Abstract

Reduction of energy consumption in the western world must be a priority if we are to reduce the rate of climate change brought about by human activity. Previous studies have shown that up to 50% of energy consumption occurs within the built environment. Therefore, reduction of energy consumption must be targeted in this field if we are to succeed in creating a sustainable society.

As the information revolution continues apace, the scope for monitoring and control of the built environment increases. The increasing interconnection of the home is leading to the possibility of offering new and innovative services, both for homeowners and public utilities. Such highly tuned, failsafe ‘smart homes’ may play a key role in future load management programs, and become an enabler for the elderly to live independently. The rollout of broadband technology with the resulting increase of bandwidth and permanent connection will facilitate the development of the smart homes paradigm.

Many new services have been identified in the arena of energy saving, but it is yet to be seen how the consumer will accept them. It is a desirable goal that the Internet enabled energy services are which give most value are provided both to the customer, and to the body providing them. In order to more fully understand the issues facing the implementers of such an energy and environment information service (EEIS), it is necessary to undergo the process oneself.

Therefore, this thesis describes the creation of a modest prototype EEIS, examining the business model in which it is proposed, and the technology that enables it, to determine if the time really is right for automated homes. A suite of services was created using a combination of pre-existing software programs resulting from research at the University of Strathclyde, new tools for other energy services, and software test tools for evaluating how a larger deployment might function.

It also proposes a suite of energy services, accessible via web browser, and assesses their utility with respect to customer value. Sample Internet energy services are targeted at typical residential users, Local Health Authorities, and Energy Utilities. They are optimised with regard to content, interpretation, and ease of use. The focus of these particular services is on how information is gathered and interpreted, rather than interaction with the home.

This thesis will conclude that whilst there is a pressing need for energy conservation schemes in the built environment, creating a stable, adaptable suite of e-Services is non-trivial and that high costs involved in hardware rollout may make such services unfeasible in the short term. In the long term however, content driven services are essential if the smart homes paradigm is to flourish and close attention must be paid to the development of these services. They must be easy for the customer to use and understand, demonstrably money saving for the utilities that will run them, and scalable and modular for rapid adaptation to new requirements.

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1 Chapter One: Overview

This thesis will address the concept of home automation in relation to its capacity for reducing overall energy demand in the built environment, and ultimately to slowing the process of climate change. A picture of the context in which such smart homes will make an impact is given in this chapter.

The smart homes paradigm encompasses many new technologies and concepts that may not immediately be familiar to the casual reader. This chapter will go on to present a brief overview of the emerging technologies and social phenomena that contribute towards this particular field, and their relative importance to this project.

1.1 Reducing Energy Demand

The reader may be familiar with the global concerns of climate change and pollution. It is believed that human activities such as the burning of fossil fuels and deforestation are contributing to a change in the natural balance of the Earth's climate. Such claims are hard to substantiate scientifically [1]. The Earth's climate has always been in a state of change and climate records do not exist for the extended periods of geological time that is needed to form a complete picture of our environment. However, the Intergovernmental Panel on Climate Change [2], as commissioned by the United Nations, has produced compelling evidence that human activity patterns will lead to a global temperature increases of between 1ºC and 3.5ºC over the next century, depending upon human response to the issues at the current time.

Although such figures are in dispute, the vast majority of scientists and policymakers agree that great reductions in energy consumption and greenhouse gas emissions per head are required in order to avoid future climate change, given the population explosion the world is experiencing.

Even if climate change were not an issue, there would still be compelling economic arguments in favour of energy efficiency in the face of dwindling resources. In short, investigation into sustainable development is a priority of our times.

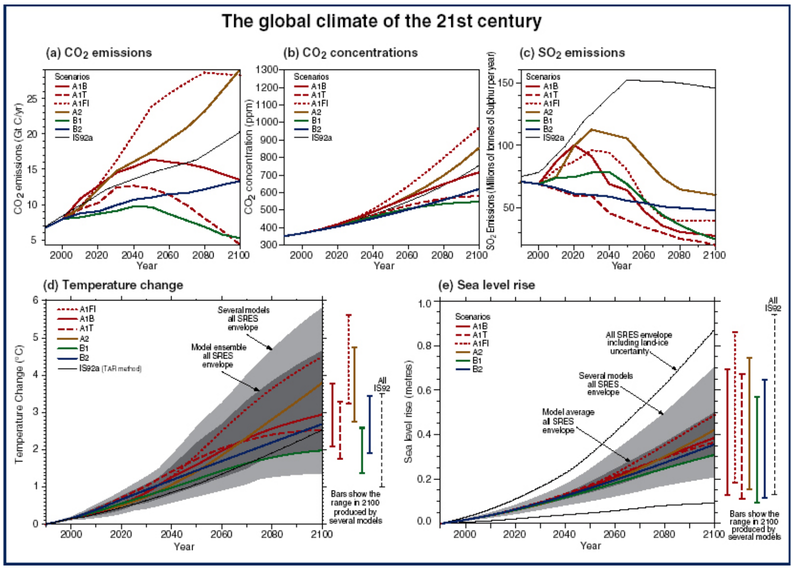

Fig: IPCC Predictions for the global climate of the 21st century [35]

Note that predicted change varies depending upon what action is taken now.

In response to the perceived problems, a number of global summits have been held in order to promote international action in climate change abatement and energy savings. To date such exercises have made moderate progress at best.

1.2 Agreements and Commitments

A major step in international agreement on sustainable development was achieved at the Earth Summit in Rio in 1992. Agenda 21 was an action plan for sustainable development, adopted by 178 countries. It identified non-sustainable patterns of human activity in the developed world as the most significant factor in environmental degradation.

It promoted the responsibility of the individual to ‘act locally’ in safeguarding the environment and identified means to do so, as well as identifying economic and social barriers to sustainability. Unfortunately, although Agenda 21 carries significant political force it is not a treaty and as such has not had the impact it deserved.

It was not until the Kyoto protocol was put forward in 1992 that major legally binding action was enabled. The UK ratified the Kyoto protocol in 1993, and has since pledged to reduce CO2 emissions by 12.5% over 2008-2010 [3].

This represents a significant challenge with some of the UK’s major nuclear power stations scheduled to reach end of life over the next decade. Either more CO2 releasing fossil fuel power stations will need to be built or a general umbrella scheme of energy saving schemes, renewable energy technologies and nuclear power stations must be implemented.

1.3 The Built Environment

The UK's Office for National Statistics [*4*] shows that the built environment accounts for some 50% of energy consumption in the UK. This statistic is common around the developed world. The situation in the UK in particular is not helped by its inclement weather or its history of poor building construction.

Space heating and electronic appliances account for most of the energy consumption in the domestic built environment. The domestic market is now a prime target for energy efficiency measures, as it will be seen that the industrial sector has nearly been saturated with schemes to reduce consumption, and can be expected to implement measures under voluntary or fiscal agreements being brought into force.

Energy may be saved in the domestic sector in a number of ways; upgrading the fabric of the home is one, but it has also been proposed that simple changes in the habits of homeowners may lead to savings that are just as significant. Home automation, the optimisation of appliance use and home heating, may bring even further energy saving benefits to rival straightforward home insulation schemes.

1.4 Convergence of New Technology

We are living in an age where technology has more impact than ever before in history. Many disparate strands of technology are reaching maturity at the present time and converging to produce applications thought to be unfeasible in previous decades. Not only are such applications possible, they are within economic reach of those in the developed world. Maturing building technologies have had impacts beyond many expectations in the reduction of baseline UK energy consumption figures of the last decade (e.g. cavity wall insulation [*4*]). We can hope that new technology will play a greater part in their reduction in the decades to come. This section recounts some fundamental advances that have taken place in information technology and networking over the past few years, and how their integration into the residential built environment will affect us.

1.4.1 Expansion of the Internet

The Internet has grown from modest roots as an experimental US government project [*5*] in 1969, to being available to over 8 million users today. It is reported that 49% of users in the UK have home Internet access, and it is estimated that 241 million active home web users worldwide have regular access to the Internet [*6*]. The second phase in Internet development in the UK has already begun with the advent of broadband. Although the UK is historically one of the smallest European markets for broadband there are indications that broadband take-up will grow, possibly exponentially with the removal of political barriers [*7*].

1.4.2 Broadband

The current standard modem line connection has a bandwidth of 56 kilobits per second and is dependant upon a time-consuming dial-in procedure. Asynchronous Digital Subscriber Line, the most common form of broadband connection in the UK, has a bandwidth of 500Kbps-2Mbps downstream (towards the user) [*8*] and is permanently connected. ADSL is commonly offered with a flat rate access business model, meaning that customers do not pay extra according to the amount of time they spend online. A flat rate, permanently connected, high bandwidth customer line offers an ideal platform for new energy services via the Internet.

It can be expected that as broadband technologies are adopted by the population at large, our homes and cities will become increasingly interconnected, with the end result that instantaneous transfer of data between any two places will become commonplace.

1.4.3 Wireless

In parallel with the development of the Internet, microprocessor technology and wireless networking technology have made significant breakthroughs in recent years. Driven by the need for portable, web connected devices in business; costs of wireless networking chips with a range of up to 10 meters have fallen low enough for consideration by the general consumer.

These fall into the two main technological camps of Bluetooth [*9*] and Wi-Fi [*10*]. Each is geared towards a different kind of networking, Bluetooth among the realm of wireless computer peripherals and Wi-Fi catering to the home networking of two or more computers. However, the relatively cheap availability of both technologies means that the more mature of the two – Wi-Fi – is being adopted with most speed at the time of writing. The combination of high broadband access and cheap wireless networking seems likely to make the smart home concept more workable than ever. This has found fruition in the development and use of wireless sensors that may soon fall in cost enough to be considered in the home.

An interesting new development brought about by the low costs of this technology is the concept of a wirelessly connected city. Such experiments are being attempted by the Seattle Networking Project [*11*], amongst others, and are an attempt to bypass the early costs of commercial broadband solutions by networking wirelessly among homes on a grassroots level. We may see 'free' wireless networks filtering down from technology enthusiasts to the public in future.

Ultimately, web enabled energy services may be carried across narrowband, broadband, wireless networking, or some other yet un-invented technology. The more common scenario in the short term is that homes in city centres will see broadband connections collecting data through wireless sensors.

1.5 Smart homes

The development of the aforementioned technologies has converged to make possible an implementation of the concepts of the smart home, and home automation.

Fig 1: Bill Gate's Automated Home [*12*]

Automated homes are traditionally regarded as the preserve of only the ultra rich, as typified by Bill Gates' house, connected by miles of fibre optic communication cable [*13*]. The progress made in the years since its completion will soon allow the typical resident to leapfrog such custom built palaces; with radio frequency sensors and actuators, that can be placed fit for purpose without invasive wiring. The image of a smart home is soon to be replaced in people's minds, from an expensive toy for millionaires, to a useful and ultimately essential tool for living to a high standard within a safe, efficient home. The creation of a smart home could be accomplished in a very short time through the installation of a gateway to the Internet, and as many wireless sensors as are required, into the home.

There exist alternatives to radio frequency communications. Power line communications send signals through the power cables of the house or between houses. However, they are currently limited in the bandwidth of the information they can send, as they are prone to electrical interference, and rogue signals from other houses. In addition, the placement of sensors is important in environmental monitoring - power line communication is limited in that respect. Power line communications have formed the basis for much smart home energy saving research in the past [*14*], and power line services are flourishing in many areas. Wireless sensors remain the system of choice, but economic factors may not bring them into the public arena for some time. Applications proposed for power line networking can still be relevant to this study. Whatever the transport method, there are still revolutions in home automation that may be put in place today.

1.6 Smart home Services

Energy saving services will not drive the general public demand for automated homes. The business model for introduction of services and content relies upon communication and entertainment as a precursor to less immediately obvious benefits. [15] and [16] give a broad summary of the range of services and they are briefly recounted here.

Communication and Entertainment

These services will deliver news, movies, media, and IP telephony to the home. The residents' primary communication with the outside world will be brought through these services.

e-Commerce

Outlets for all kinds of goods are transferring their services to the Internet. This reduces costs and allows them to address a much larger customer base. Electronic commerce services are general shopping services, reducing the need for building retail outlets in the urban environment and adding to leisure time.

Telemetric and Energy, and Home Automation

These services transmit low latency information about the home and its surrounding environment to and from a central server. Information from the home can be analysed and returned to the customer by a utility, or information about the home's surroundings can be brought to the customer.

Information about the home's energy use can be automatically collected by the utility and the customer billed accordingly. Home automation services may interact with connected devices in the home, regulating temperature and energy consumption.

Security and Home Care

These services provide extra monitoring for the safety of the home and its occupants. They can provide information about the safety of the indoor environment and security for the elderly.

1.6.1 Service Categories Explored in This Study

This study will encompass services in the areas of telemetric, energy and home automation, and security and home care. Many services can cross the boundaries between these broad definitions, and elements of e-commerce and information and communication are relevant as well. However, it is important to have an idea of the relative placement of service categories in the business model. Straightforward communication, information and e-commerce services are expected to be the ultimate driving forces behind home gateway uptake. Telemetric services either will be supplementary additions once the infrastructure is in place, or funded through local authority initiatives.

1.7 Monitoring Services

The primary requirement for a residential environment & energy monitoring service is to acquire data, store it, and display it to interested parties. We want our services to monitor both energy consumption and aspects of the indoor environment. Once these are in place, we can analyse the raw data to produce interpretations that are more valuable.

Fundamental to the monitoring of energy consumption and indoor environment are:

- **Fuel Consumption (Electricity and Gas)**
- **Temperature**
- **Humidity**

Electronic monitoring of these parameters is a mature industry, and sensors are readily available. Also readily and cheaply available in sensor form are:

- **Occupancy**
- **Carbon Monoxide**

This basic range of parameters has a wide range of applications. The unrestricted flow of information enables new ways of ensuring safety, preventing profligacy or unwise frugality in energy consumption, and addressing health concerns by monitoring the built environment around us.

1.8 Control Services

Although data gathering and information services may be useful in themselves, energy utilities and householders may be able to make more significant and rapid savings through a more active approach to energy conservation. These strategies are in the domain of demand side management. Although the infrastructure required puts DSM beyond immediate use in this project, it is one of the primary long-term goals of energy related smart home projects and is undoubtedly a subject for future study. Therefore, we discuss it here at a general level.

1.8.1 Demand Side Management

It is commonly said that Demand Side Management is the cheapest resource available to us, compared to the cost of harvesting and distributing any other energy resource. DSM is the term given to a variety of strategies both to smooth the system load curve, and to reduce demand in general.

DSM has been utilised for some years, although not solely in the name of environmentalism. It has been used to reduce spikes and troughs in demand, which affects substantial savings in energy production and distribution. However, the advantages of DSM can be seen not only in primary demand reduction and load curve smoothing but also through savings in infrastructure and increased reliability. Therefore, it is significant that energy utilities seek DSM, which would theoretically result in lost profits, but actually results in net savings.

The U.S. Energy Information Administration defines four techniques commonly used in the reduction of demand for energy [*17*]:

Load Shedding

This is a general reduction of energy demand, with no base on specific times. Installing an energy efficient light bulb in a customer's home would be an example of this strategy.

Peak Clipping

This refers to reducing consumption at times of peak demand, either through raising spot prices or through implementing voluntary schemes that interrupt supply at peak times.

Load Shaping

This consists of smoothing the load curve through various methods.

Load Building

This consists of filling the troughs in demand that may occur e.g. at night time, generally through reducing spot prices or scheduling high-demand processes for these periods.

The range of tariffs offered by any electricity utility can be seen as a form of DSM, allowing the utility to influence the subscriber's energy demand profile in a very general way and thus encouraging peak clipping and load building.

1.8.1.1 'Weathercall' and CELECT

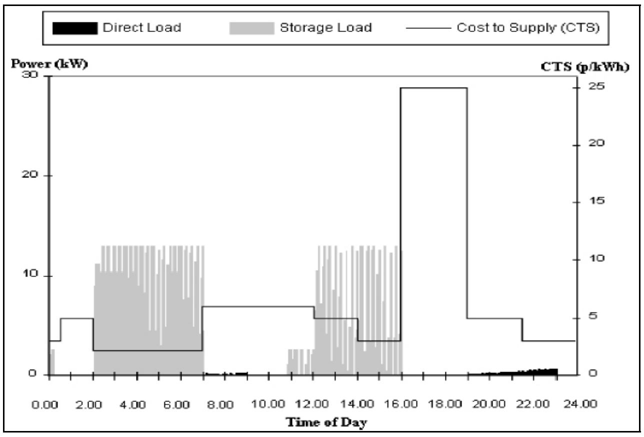

Fig: Response of the CELECT system to a cost reflective message

A more hi-tech example of DSM is Scottish Power's 'Weathercall' system. This system uses inaudible 198 kHz radio signals to control storage heating loads. This utilises peak clipping, load shaping and load building to smooth the power demand curve of space storage heating through the day. The 'Weathercall' programme has been a commercial success, and is offered alongside Scottish Powers other tariffs.

This concept has been developed with the Electricity Association's CELECT project [18]. CELECT offers a sophisticated central heating control system that takes unit cost, climate, and user occupancy into account in order to optimise heating times. It is claimed that such a system reduces electricity consumption by 13%. The figure shows the response of the system to a cost reflective message (i.e. gives the entire cost of supply throughout the supply chain).

1.8.1.2 Direct and Indirect DSM

There are many variant strategies on DSM, with varying degrees of complexity. Two major philosophies in DSM are direct and indirect DSM. Direct DSM is a cutting of the energy supply to any particular house at a given time. Indirect DSM is where a signal is given to the house in question, to utilise peak clipping through the scheduling of appliances i.e. a washing machine might delay its cycle for a few minutes.

A key application for smart homes is in energy saving, both through customer awareness of energy issues and indeed through direct demand side management at times of peak load. Indirect demand side management through a home gateway controlling individual appliances is also an attractive option. [*19*]

At its most general, an EEIS monitoring service is an indirect DSM facility. The long-term goal of any EEIS is the reduction of energy demand by the homeowner, leading to less generation facility in the long run.

1.9 Smart Home Services

1.9.1 Pilot Studies and Existing Schemes

While high profile pilot projects and commercial websites for smart homes are generally quite abundant [*20, 21, 22*], studies in the narrower field of energy conservation and environmental monitoring are more limited. Whilst research into Building Energy Management Systems is widespread, a select few publications address energy conservation within the new framework of Internet energy services and residential buildings. Some existing automated home projects are reviewed here.

1.9.1.1 Sweden

Sweden is one of the most web-connected countries in Europe and as such, it has a well-established tradition of research into the automated home. It is also host to some of the best-orchestrated projects on connected, automated homes.

1.9.1.1.1 Energy Barometer

The Swedish 'Energy Barometer' project [*23*], piloted in 1996 and run in 1998, consisted of a building energy end-use monitoring system run by University College of Gävle-Sandviken. It featured funding and set top boxes provided by Ericsson. Its stated aims were:

- To determine levels and determine rates of change of energy levels in Sweden
- To provide useful data for future projects

A major technical goal of the project was to provide energy consumption measurements for single-family houses, with consideration of internal temperature and external temperature, accountings for the summer period when heating costs are lower. The pilot in 1996 featured a study of four houses. However, before the next phase of 1000 houses was implemented, a simulation system of energy consumption in about 700 houses was created in order to test the routines used to gather data and the statistical methods used to analyse it. An 'energy signature' was created for each house, being a statistical model of the house, combining technical parameters and geographical climate.

The details stored on each house included number of occupants and number of appliances, while the Swedish Meteorological and Hydrological Institute provided climate details. These allowed detailed technical models to be built up for estimating energy consumption. Notably, the emphasis of the project was on estimating overall energy consumption in a town as opposed to creating information services for customers. The Energy Barometer project has been the basis for much further research and its success has contributed to the founding of further smart homes projects.

1.9.1.1.2 ISES Project

The Information/Society/Energy/System project [*24*] began in 1996 and aimed to understand the impact of new technology upon energy consumption and society in general. It discussed the possibilities brought about by 'smart equipment' i.e. automated meter reading, distributed agents etc.

It addressed such subprojects as:

- Developing electronic information tools integrated in energy distribution
- Understanding technical information exchange mechanisms in large distributed information systems

- Understanding human information exchange mechanisms
- Evaluating applied technology for efficient information systems

By nature the study was generalized and strategic. Some important points to emerge from the project were the need to cater both to vendors and to customers in information service design, and the proposition of using smart equipment for large-scale deployment of energy information systems.

1.9.1.1.3 KEES Project

The Karlshamn Energy Efficient System project [25] ran from January to September 1999 under the supervision of EnerSearch AB as part of its international IT in Energy research and development programme. It built on the ISES project that had preceded it. The aim of the KEES project was:

'to study the potential for energy savings and services especially in a liberalized market environment, taking into account the many new market as well as technology changes in the energy and IT sectors.' [26]

Under this aim, the project made several investigations into how smart home technology would be implemented, and how it would affect energy demand. It incorporated exposition and study of an implementation of the Energy Barometer system. The results of the Energy Barometer project and the KEES project inform much of the research done under later projects.

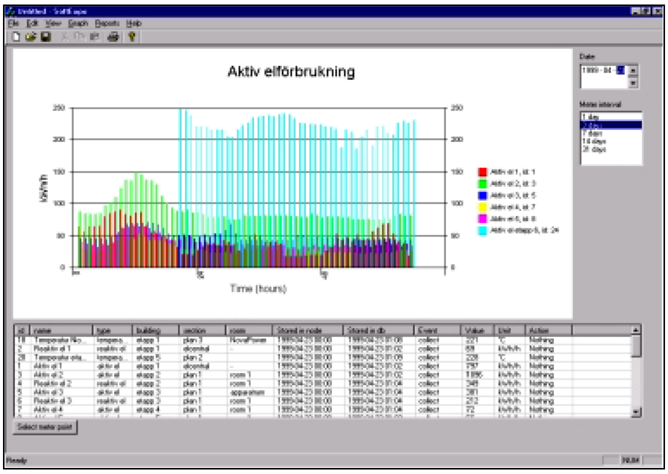

Fig: A demonstration screenshot from the KEES project

('Aktiv elförbrukning' = Aggregated energy consumption)

In addition to research explicitly into the 'smart home', the KEES project determined to look at the impacts of the market and technology trends in energy from the perspective of the customer, and to propose new possibilities for energy management in buildings.

Inquiries into trends in energy saving amongst the customer base suggested that larger customers i.e. businesses were already convinced of the benefits of energy saving. The major barriers to adoption of energy saving measures were payback timescales and cost benefit.

Smaller customers i.e. residents were generally very keen on energy saving and saving money but had little idea what was required to be done in order to do so. They were also interested in more detailed statistical electricity bills. Note that although the enthusiasm of the respondents is encouraging it is important that customer surveys are distinguished from actual behavior – there has been a relatively small take up of explicitly ‘green’ energy tariffs in the UK. It must therefore be assumed that money saving is a major motivating factor in customer adoption of advanced energy services.

Given that more energy saving opportunities existed at the demand side rather than the supply side in the Karlshamn project, it was hypothesised that the provision of ‘smart’ energy services to the home would potentially generate a profit. In the intervening years, continuing EU legislation has made the good case for connected homes even better.

1.9.1.2 UK

1.9.1.2.1 University of Strathclyde

The University of Strathclyde has produced a number of MSc theses and projects over the past few years with conjecture on possible smart home services.

- **Standby power saving**
    - It is claimed that appliances left perpetually in ‘standby’ mode account for up to 10% of residential electricity use in developed countries [*27*]. A Strathclyde project proposed an online ‘standby service’, which would switch appliances off automatically when they were not being used.
- **Gas sensor, Cold Alarm, CO Alarm**
    - Strathclyde studies have suggested online warning systems for a number of common dangers facing the elderly or infirm in their homes.
- **Mould Detector**

- Mould and damp is a common problem in Glasgow housing. [*28*] A Strathclyde paper reported on the results of research to predict types of mould growth based on recordings of relative humidity and temperature over time [*29*]. Such a system could easy to implement online once the sensors were in place.

1.9.1.3 Commercial Services

Business to business online energy information services are well established in the commercial world. At the time of writing, an Internet search could find a number of such demonstration services, although none featured the specific analysis features nor the explicit customer orientation aimed at in this project. Some examples of commercial energy information services are presented here.

1.9.1.3.1 Stark Online

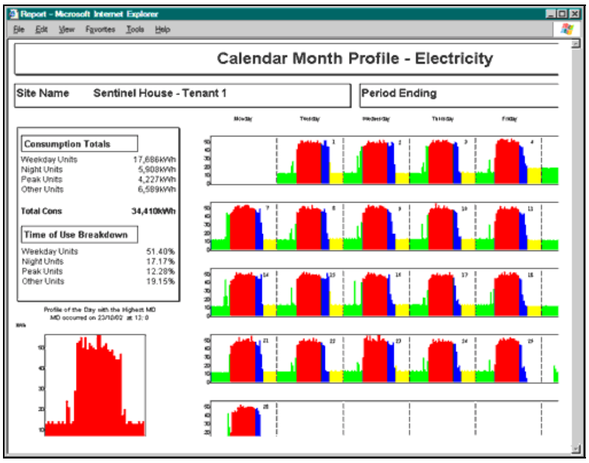

Fig: An example Stark Online report

Founded in 1982, Stark software [*30*] is focused on producing energy information systems. Major utilities and energy consumers around the world use Stark products. In 2002, it became the first independent company in the UK for four years to be an Elexon [*31*] accredited Half Hour Data Collector and Aggregator. It has recently produced an online report facility for subscribers to monitor their energy usage online. Stark offer a number of report types for which parameters can be modified. Report types generally consist of multiple graphs over a single page.

Stark's focus ranges from multi site organisations to small enterprise. Data collection is also restricted to half-hourly readings.

1.9.1.3.2 ABB Systems Energy Profiler Online

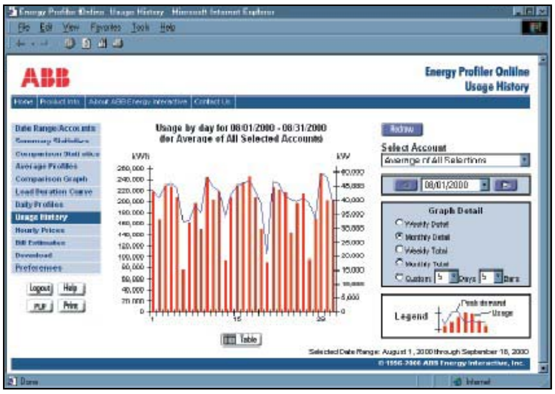

Fig: An example ABB Energy Profiler Online Report

ABB systems [32] offer a diverse range of power and automation technologies for industry, with a history of some 120 years. Their energy profiler online is a service for utilities to allow large customers to view their usage online. Information can be shown for multiple sites, grouped by region or building type.

Energy Profiler Online allows energy providers to send their customers real time pricing signals, and to implement load curtailment programs (DSM). Given this capability, it is an advanced example of an energy information service for business-to-business use.

1.9.1.3.3 SMR Utility Manager Online

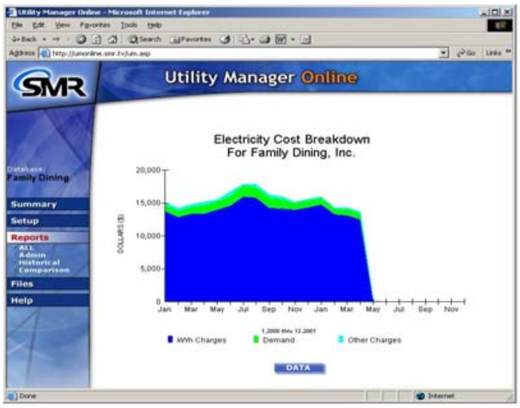

Fig: An example SMR Utility Manager Online Report

SMR ('Save More Resources') [*33*] offer a very well presented energy information service targeted at small businesses seeking to view consumption and cost information. It provides options to identify cost savings and detect bill irregularities. The utility manager updates directly from the energy provider on a long timescale and therefore constitutes energy accounting software as opposed to any notion of real time monitoring. Nevertheless, it serves as a useful case study in presentation of results.

1.9.1.4 Opportunities in the Energy Services Market

Given that commercial energy information services are becoming widespread, the EEIS to be created in this project must provide new functionality against what is already available. There must be a clear differentiation from current practice.

Each example given here is a business-to-business vendor either limited to commerce and small enterprise, or seeking to expand into the residential market from that position. Their data transport methods are through narrowband POTS (plain old telephone system), private networks, or even manual readings from data loggers.

A niche now exists for a service tailored directly to residents' needs, which can be deployed cheaply through the growing broadband network in the UK. Amortisation of costs is key in this concept; as it is clear that telemetric services for the home have been high cost up to this point. Given that the benefits of energy efficiency are delivered over the long term, it is important to keep the subscription cost, especially if it is not subsidised by energy utilities, to a minimum.

An EEIS will of course also differentiate itself through the provision of new services related to health and safety, which are not covered by most of the commercial systems available today.

1.10 Research Objectives

There are a number of benefits in constructing an example of an Online Energy Information Service; not least, that implementation will bring to light many details that were not considered at its first conception. This will broaden the knowledge available and bring a deeper understanding of the challenges facing those who implement such services.

1.10.1 Proof of Concept

The implementation of an online Environment Energy Information Service goes beyond the detailing of services and description of platforms. It includes administration of the back-end systems, i.e. data collection and all the issues associated with it, database design, the implementation of a secure e-services platform and even web design issues.

A primary goal of this project is to implement a modest example of such an EEIS. This serves both as proof (if it were needed) that such a service can be put into practice; and also to evaluate the feasibility and cost to a mid-sized electricity utility/health and safety authority of rolling it out for a particular number of residents, given a number of different market situations.

Of course, extrapolation of a simple prototype system to such a scale is a notoriously difficult practice, with a high degree of unknowns and a large margin of error. However, experience shows that a prototype can give rise to better estimates as opposed to a simple paper exercise, which may neglect implementation issues. It is hoped that a general appraisal of costing and implementing such a service can result in a general statement on feasibility even under conditions of uncertainty.

1.10.2 New Services

The number of services that can be provided through smart home data is deemed to be near limitless. This project aims both to provide established services through the new medium of the Internet, and to present new functional services that have been suggested by prior research.

1.10.3 Evaluate EnTrak as a basis for the service

This project will use test data from the EnTrak system developed by Strathclyde University [*34*]. It aims to evaluate the format of the captured data for suitability for a real-time energy information service, suggesting several new parameters that should be incorporated into its design. An outcome of this project will therefore be an evolution of the EnTrak database, consolidating its position as multipurpose energy management and decision support system.

1.10.4 Optimise User Interface

Much has been made of the need to include the energy customer in the selling and buying process in order to provoke thought on their consumption of resources. End users are non-technical and it is believed that the user interface must be tailored to their expectations. It is hoped that new e-services may be developed designed specifically to engage the end user and modify their behaviour with regard to energy consumption.

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2 Chapter Two: Technical Overview

Now that a review of smart homes concepts has been presented, this chapter presents a deeper view of the issues to be tackled. It touches on energy monitoring, health and safety issues, and aggregate energy monitoring. We then go on to look at specifics concerning how such energy information services are implemented.

2.1 Target Markets

Two types of end users may benefit from these services: the resident who pays for (or joins a scheme supporting) this service, and the power utility or health and safety manager who can improve their business.

2.1.1 Private

Previous studies have noted that private residences represent the greater opportunity in implementing energy saving measures: larger customers of energy utilities may already have implemented energy saving measures due to commercial pressure. It is imperative that the private homeowner understands exactly why it is important to them to save energy. [*1*]

The residential user of this service may well be new to this kind of technology; indeed the primary market for health and safety and homecare applications is the elderly. Given this, should any user interface be required it is important that it be as simple and intuitive as possible. It should also give the user an incentive to use it regularly; the best motivator in this case is money, but social prestige may also be a factor. [*2*]

2.1.2 Utilities

Utilities already operate in a high tech domain; they would be expected to run energy management software already. There are also health and safety applications for such information services – this represents a new opportunity for regional health authorities. In both cases, the web-based nature of the services is a step forward, even if only in terms of flexibility and mobility for the operator.

Energy utilities and regional health and safety managers have a different set of demands for their user interface. Generally, the user will be familiar with the issues at hand and their primary goal is to get their information as soon as possible. They may spend long periods of time consulting the service. On the other hand, the online nature of this service is particularly suited to mobile monitoring and a mobile health and safety officer may require a service that is clearly visible on a laptop PC screen.

2.1.3 Demand Monitoring

Half-hourly energy monitoring has been seen as the holy grail of automated meter reading for some time. Generally, this has only been accomplished through expensive auxiliary equipment in tandem with a price hike in the service, which must be offset through offering extra services [*3*]. It is believed that the cost of AMR in this case can be amortised through the wide range of services that can also be offered.

Energy monitoring is important to utilities for demand profiling and forecasting activities. Estimates of future demand will have significant impact upon cost of supply. There are a number of techniques used for demand profiling, with direct demand profiling (energy monitoring direct from the customer's meter) seen as the most effective. Utilities may forecast demand over the next day or week, taking into account factors such as weather forecast and daylight hours.

Customers may be classified by consumption pattern, leading to a load profile on which the utility can base bids to the energy pool. Load profiles are made more accurate through direct demand profiling, by which a utility can construct a dynamic load profile as opposed to a static one based on historic research. Taking a representative sample of such metering is known as dynamic metering [4].

2.1.4 Health and safety

From the amount of research dedicated to energy saving through online technology, it could be construed that this was the only application for automated homes. However, health and safety have always been seen as concerns that can be addressed through communication technology.

From an environmental perspective, air quality and temperature alarms are the best ways we can help the elderly and those most at risk from hazards in the home. However, automated homes do provide the facility for 'panic buttons' and intruder detection. These may also be of interest to health and safety organisations.

Measurements of gas leaks, CO leaks, temperature, humidity and occupancy can be made in order to ensure the safety of residents. As the population ages such services will become increasingly favourable over supporting the elderly in homes or providing care workers at all times.

2.1.4.1 Health and Safety Sensor Placement

2.1.4.1.1 'Social Robustness'

Previous research projects in the literature review have emphasised the importance of 'social robustness' as well as physical robustness. This means that sensors must not interfere in the day-to-day lives of the residents of the house. This is doubly important in a commercial service where the residents may be paying for the privilege of having them. Wireless sensor configurations are a primary means of increasing convenience for the householder, as well as enabling optimum placement.

2.1.4.1.2 Gas

Sensors for detecting gas leaks of all kinds are best placed in the rooms were appliances that might cause such leaks are situated. The British Standards Institute recommends placing sensors in every sleeping room, and remote rooms where alarms may not otherwise be heard. They should be placed above door and window height.

2.1.4.1.3 Temperature

Temperature sensors, if used to evaluate thermal comfort, are ideally placed as near to where the occupants are as possible. Temperature sensors will be placed hanging in the centre of a room for research reasons; this may not be possible in a commercial service, so placement on a bounding wall is recommended. If more than one sensor is available, they should be placed at warm and cold extremes in a house: generally a bounding wall and an exterior wall.

2.1.4.1.4 Humidity

Humidity sensors placement depends on the purpose for which the humidity is being measured. If they are being used to detect the possibility of mould they should be placed at the extremes of temperature, generally one should be near a window where condensation problems are highest. Humidity may also be used to calculate comfort levels in the home.

2.1.4.1.5 Occupancy

Occupancy sensors are best placed in a main room or in an entranceway if activity patterns are to be monitored. In this way, a health and safety manager could tell whether an occupant had left the building within the last day or so, without impinging on the occupant's privacy.

2.2 Energy Management Systems

Any EEIS will of necessity be underpinned with a sound information management system. This is the central hub of the system where information is gathered, analysed and dispatched to the end user. There must be due regard for volume of data storage, security and robustness, extensibility and ease of use.

2.2.1 EnTrak

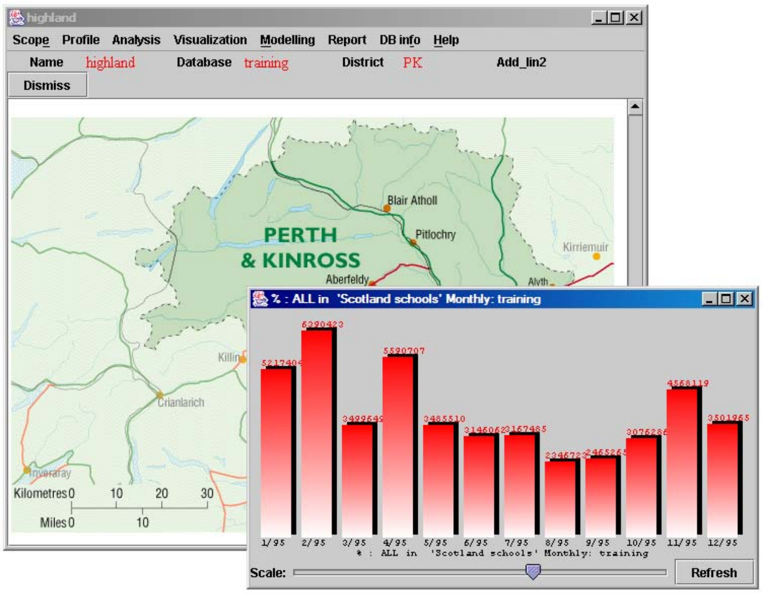


Fig: A screenshot of EnTrak's GUI

It is proposed to use the EnTrak building energy management tool as a platform for the central storage and organisation of the gathered data. The flexibility of the EnTrak system lends it readily to expansion and some pre-existing analysis facilities may be readily converted for online use.

The EnTrak system comprises a decision support tool for large-scale monitoring of fuel consumption and energy use targets. The philosophy behind EnTrak, GIS [5] enabled, is to promote renewable energy technologies by providing geographical and temporal information on demand patterns, and to provide an analysis facility for assessing whether renewables may be better deployed in a building than importing energy from the grid.

2.2.2 EnTrak Functionality and Characteristics

Among EnTrak's main features are:

- **Database scoping**
  - It allows groups of entities with a similar characteristic or location to be grouped together for assessment.
- **Entity classification for fuel consumption**
  - This feature supports the classification of entities in the database into specific bands of fuel consumption.
- **Data of any frequency, detail, and type may be recorded**
  - Given the variety of parameters to be recorded by the EEIS system, it is vital that their storage is flexible and easily adaptable to new features.
- **Geographical maps for user interaction**
  - Although geographical maps are not intended for inclusion in this simple demonstration system, network management programs generally feature a geographical element in their interface. Future expansion would most probably call for inclusion of this feature.

2.2.3 EnTrak as a Multi-target Energy Information Service Platform

EnTrak's flexibility lends it to conversion to new applications and features. It is now proposed that a new version of EnTrak evolve to include an Internet enabled element in its definition, and to include provision for residential services in addition to its current services for energy managers and utilities.

The need for such platforms for information services was emphasised in the literature produced by the ISES project. They must be customer facing as well as oriented towards the operator. Such a component is a crucial consideration in the design of an EEIS.

2.3 The e-Services Model

The model of residential Internet access and connectivity is changing from a narrowband centred view to a broadband model, where access providers take on a more proactive role in providing content and services, among the standard Internet access. Such services will drive the market for broadband connections for the average user, providing the business model.

At the time of writing, a fierce commercial battle was being fought over who provided the ‘digital hub’ linking electronic services provided to the home [6]. There are models based on PCs, set top boxes, even games consoles, and some parties even contend that there will be no ‘hub’, merely a set of wireless appliances connecting directly to the Internet.

However, the result of most such models is the same – a more and more fully connected home with a single connection to the outside world, providing both flat-rate broadband connection to the Internet and specific commercial services to the end user. The range of such services has already been discussed, but the model of how they will be delivered will be addressed here.

The Ericsson e-Services model [7] has been proposed by a consortium of businesses, in conjunction with the Swedish mobile phone manufacturer Ericsson. The combined power of these companies and the relatively advanced stage of the project appear to guarantee the model a leading position in the European market. The e-services model also embraces open standards allowing independent development by any number of service providers, a significant difference from many of its competitors.

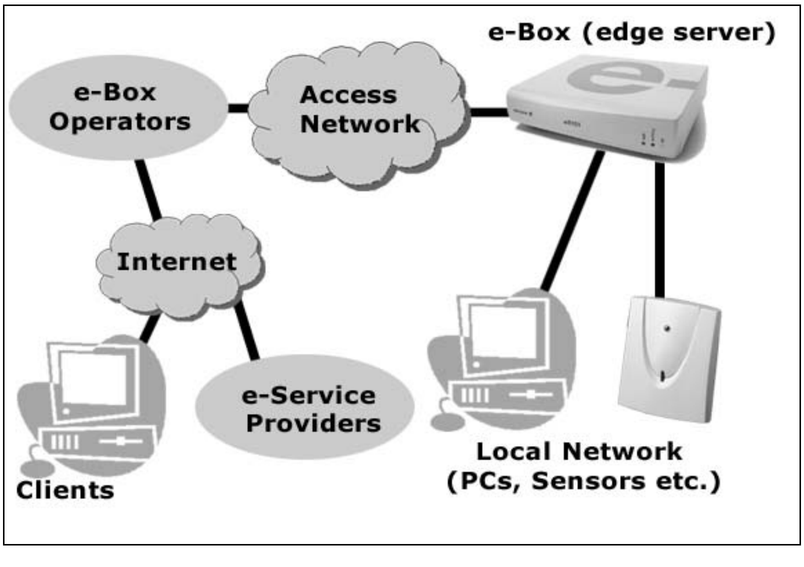


Fig: The Ericsson e-Services Model

The e-services model represents an evolution of the current structure of network operators and their alliances formed with content providers to segregate content based on supplier. The e-services model proposes a shared platform in which a network operator will contract with service brokers over many independent content and service providers. The intent of this is to liberate the market for the benefit of all.

The means by which Ericsson intends to do this is through a well-designed services model adhering to open standards, allowing entry to the market for independent operators. Ericsson's set top box is based on the OGSI model [*8*], using Java technology and standard PC connectivity. As such, it is an easy platform on which to develop applications.

The set top box (or e-Box) is referred to as the edge server or home gateway, acting as an interface from the home network to the wider Internet. Through the access network, it will connect to a management system that will maintain the e-Box network. Such an e-services centre will broker a range of services from third party e-service providers from the Internet proper. This distributed model for e-service provision is intended to encourage a wide range of services.

2.3.1 The Ericsson e-Box

The Ericsson e-Box is the edge server in the e-Services model, an extremely flexible set-top box system designed for multiple networking configurations and high availability. It may be used as an Internet gateway for a home PC network, or simply installed as a set-top box permitting video on demand or sensor data gathering.

2.3.1.1 e-Box Hardware

The e-Box is a compact piece of hardware with low power requirements and solid-state storage for high availability. Particularly of note is the variety of networking ports and configurations that allows adaptation to many pre-existing formats. There is provision for the e-Box to function with PC-compatible peripherals, utilising the extensive base of peripherals that have already been developed. An example configuration of the e-Box interfaces comprises:

LonWorks interface

This is a powerline communication interface for an alternative sensor configuration.

RS232C port

This standard serial port can be used for connecting PC style peripherals and remote sensing base stations.

Two 10BaseT Ethernet Ports

One port connects to an external broadband modem; the other connects to the local network.

Other networking hardware configurations are available for different service models. This may be customisable on a service-by-service basis.

2.3.1.2 e-Box Software

A number of UNIX like real-time operating systems may be run on the e-Box. In addition to the basic **operating system**, the e-Box will contain as standard:

- **Drivers for external and local network access**
  - These allow the e-Box to communicate both with the local network and with the wider Internet.
- **Server components**
  - The e-Box user interface is initially through a web server that is run on the machine.
- **Java Virtual Machine**
  - This provides a runtime environment for custom software from e-Service providers.

2.3.1.3 e-Box Architecture

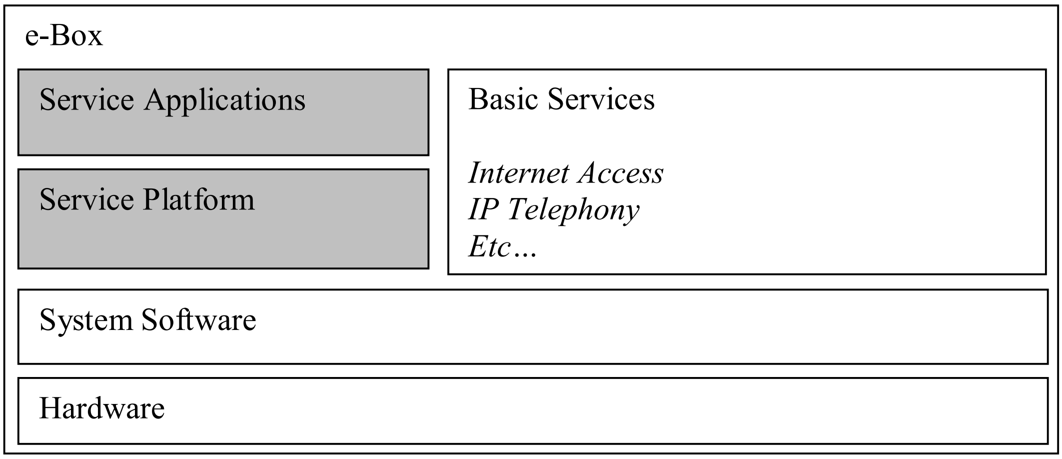
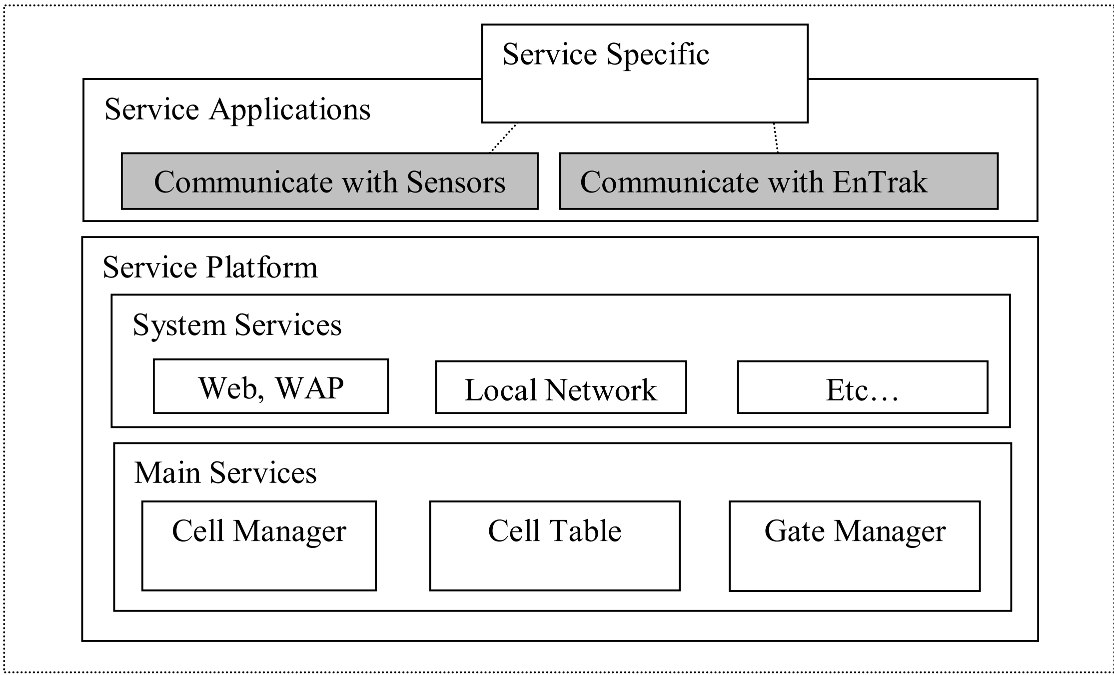


Fig: A representation of the e-Box Architecture

The e-Box architecture is divided into a number of component blocks, each layer communicating with the one below. The service layer is split in two for security reasons: the Basic Services interact directly with the system software, whereas the Service Platform is restricted in its access. This reflects its role as a platform for volatile end user services that may be downloaded or erased, preventing hostile or unsafe code from accessing the underlying system. It is in the Service Platform and Service Applications areas that an e-Service provider will deploy their code.

2.3.1.4 Service Applications



e-Box Services Platform

Above the hardware layer and system software rest the services layers. The service platform comprises pre-configured e-Box services for controlling the system. e-Box services are contained in a structure called a cell, which represents their access rights to the system. The main services layer contains services for cell management in the system services and service applications layers. The system service layer contains core services such as the e-Boxes own web server and networking routines. An e-Service provider may deploy a service here that interacts directly with hardware.

On top of the service platform is the Service Applications layer. It is here that e-Service providers will generally deploy their own software. Software from an e-Service provider may be written in the standard Java programming language. Such code will be packaged in a 'boxlet' analogous to a Java jar file. A boxlet will execute in a cell, which is broadly analogous to an operating system process.

The procedure for running a boxlet on an e-Box is therefore to download the boxlet package, register it with the cell manager, and send a start signal to the cell that runs it.

Boxlets may be easily be written and tested on a standard PC, in conjunction with e-Box simulation software. An e-Box may even be fully simulated on a PC, so that the boxlet code can be tested before hardware becomes available.

2.3.1.5 Sensor Hardware

Although the market for wireless technology is booming, the wireless sensor market is immature at present. The e-Box's "PC like" networking capabilities make it a simple procedure to run different types of sensors from the RS232 port. Wireless and wired sensors may be run in parallel or as alternatives. During testing, wireless sensors created by Easy-Living SE [9] were available. Ericsson supports Easy Living in an attempt to kick-start the wireless sensor market. However, pricing information for Easy Living sensors was difficult to come by at the time of writing and their capability of producing large quantities of sensors is in doubt. Other wireless systems exist but generally provide wireless stations to which a sensor must be attached – introducing a cost greater on its own than each sensor.

For the purposes of the project, wired sensors are used for some of the testing, and cost of wireless sensors is assumed for the costing exercise.

2.3.1.5.1 Sensor Technology

A brief overview of the sensor configurations that are available for testing and deployment is given here. The requirement for accuracy is not as pressing in the domestic environment as it may be in industry, and cost and compatibility issues have equal consideration. Where possible, sensors that are easier to integrate with wireless technology are given preference.

Temperature Sensor Types [*10*]

Temperature measurement is probably the most widely used of electronic sensor technologies. There are three main types of temperature sensor: thermocouples, RTDs, and lately, Integrated Circuit type sensors.

Resistance Temperature Detector Sensors operate by utilising an increasing resistance in proportion to temperature. They are typically composed of platinum, nickel, or copper. The material used for the RTD has a direct effect on price – platinum has the best properties but is also the most expensive.

Thermocouples are two dissimilar metals joined together at one end, which produce a voltage with change of temperature. There are many combinations of metals that may be used, each with slightly differing properties. Thermocouples are historically the cheapest and most popular of temperature sensors, but errors can easily be introduced in the absence of signal conditioning hardware.

Integrated Circuit Sensors are a relatively new arrival in sensor technology. They are based on silicon's change electrical resistance with temperature. A silicon semiconductor will give useful temperature limits of –55°C to 150°C. Although IC sensors have a much reduced temperature range and response time, they offer high linearity and are much cheaper than the alternatives.

	Range	Accuracy	Response Time	Linearity
RTD	–250°C to 900°C	± 0.1°C	1-10 Secs	High
Thermo	–270°C to 1821°C	±0.5°C	<1 Secs	Moderate
IC	–55°C to 150°C	± 1°C	4-60 Secs	Best

Fig: A direct comparison between RTD, thermocouple and IC sensors

Given that the sensors are destined for domestic application, that sensors will be co-located with an RF PCB, and that cost is an issue; IC temperature sensors are the preferred solution in this case.

Humidity Sensor Types [*11*]

The main types of RH sensors for domestic applications are of the capacitive and resistive varieties. Generally, an integrated circuit type sensor will combine one of the analogue sensors with a transmitter and may include onboard signal conditioning circuitry.

	RH Range	Linearity	Response Time	Stability	Accuracy
Capacitive	3 to 95%	± 2%	45 Sec Max	0.5%RH/Year	± 3% RH
Resistive	20 to100%	Logarithmic	15 Sec Max	1%RH/Year	± 5% RH

Fig: A direct comparison between capacitive and resistive sensors

A capacitive sensor works on the basis that changes in RH cause the capacitance of a film of hydroscopic polymer to change. A resistive sensor works on the basis that resistance change across a polymer element varies with relative humidity. Both sensor types require a transmitter to produce a higher-level voltage or current signal.

Both sensor types are believed to be adequate for our purposes but capacitive sensors offer marginally better stability and accuracy and are more common in integrated IC type sensors. Given the intention to use the humidity sensor for domestic applications and the preference for an integrated IC-type sensor for connection to a Radio

Frequency transmitter, a capacitive sensor will best suit the requirements of the humidity monitoring service.

2.3.1.5.2 Easy Living/Wireless sensors

Easy Living radio frequency sensors communicate to a 'base station' connected to a serial port – such as the one on the e-Box. They use an Ethernet-like protocol whereby each sensor has its own IP address.

Sensors are battery operated allowing optimal placement, with a data rate of 10kbps. They have a range of some 300m. The sensors available or soon to be available from easy-living are:

- Temperature
- Relative Humidity
- Motion Detector
- Actuator

Detailed technical and pricing information on the sensors is difficult to obtain. Strathclyde University have obtained a demonstration suite of sensors with accompanying code. This was used in some testing of the EEIS, but pricing information was not available for commercial applications. Easy Living sensors are useful for demonstration purposes but cannot be considered suitable for a large-scale implementation of residential energy e-services at the current time.

Other wireless solutions are available commercially but each is a custom system designed by the manufacturer. The cost of wireless sensors varies dramatically according to application and vendor. Vendors tend either to sell systems for industrial applications or to provide their own closed service for home use. The middle ground of a modular, flexible system that may be utilised for our purposes is conspicuous in its absence.

2.3.1.5.3 Wired Sensors

There are many suppliers of RS232 bus based data acquisition systems, with wide variations in cost, features, and available information. They range from cheap PCBs that connect IC sensors to RS232 connectors, to independent Data Loggers with many features and great flexibility, providing onboard signal conditioning for analogue inputs.

Just as RS232 systems may be connected to a PC, they may also be used with an e-Box. Temperature sensors are by far the most available of wired solutions, and production of thermocouples and their associated equipment is an industry in its own right. Unfortunately, there is no single integrated system that will provide all the sensors required in the project, and interface to an RS232 port. Such a system must be either commissioned or custom made.

2.3.2 Other Technologies

As well as the hardware to be used in the project, there are a number of software choices in its implementation. The platforms used in the implementation of this project are briefly detailed below. This project uses Java 2 Enterprise Edition Java Server Pages to generate dynamic content, using Java Enterprise Beans derived from the original EnTrak code to query a MySQL database.

2.3.2.1 MySQL Overview

MySQL [1] is an open source [2], free implementation of a database using Structured Query Language to retrieve data using simple query terms. It underpins the EnTrak energy management software.

Structured Query Language is a standard interactive and programming language used to get and set information in a database. SQL is an ISO and ANSI standard, but MySQL uses slightly non-standard extensions and behaviour.

MySQL is reliable, well documented and supported. It is the database system of choice for many popular data driven websites, and boasts impressive speed and flexibility even compared to commercial database applications. Of particular interest is the ability to handle a number of simultaneous users limited only by hardware, and to handle more than 50,000,000 records. Recent developments have included the ability to support transactions – essential for secure e-commerce.

2.3.2.2 J2EE Overview

Java 2 Enterprise Edition (J2EE) [3] is the mechanism by which dynamic web pages are represented to the end user. Enterprise Edition is a web enabled version of the popular object oriented programming language Java [4], provided by Sun Microsystems.

J2EEs design aims are to reduce the cost and complexity of developing services with clients, middleware and data resources. It does this through a standard architecture that promotes the role of the middleware in an enterprise application, and dividing it into customer facing and data resource facing aspects.

In order to be web enabled Java programs must be presented as servlets, mini applications that receive HTML requests and send HTML replies.

J2EE has special strengths in that servlets can be created from embedding a little Java code in a standard HTML page. These are known as Java Server Pages. Server pages and servlets can be used interchangeably and may forward information between each other. J2EE can also utilise non-servlet Java programs (and communicate with them) by ‘including’ them as Enterprise Java Beans.

J2EE is therefore easy to use with pre-existing Java code and straightforward to create web pages with. It is for these reasons that J2EE is selected as the platform of choice for our e-Services.

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10. Choosing and using a temperature sensor
    a. *Sensors Magazine - July 2001 VOL. 18 NO.7*

11. Choosing a humidity sensor, a review of three technologies
    a. *Sensors Magazine - July 2001 VOL. 18 NO.7*

3 Chapter Three: Development and Testing of a Prototype EEIS

A modest example of an EEIS was set up in this project in order to understand the issues involved with implementation better. This chapter establishes the reasons for creating an implementation, details how the work was done and sets out the limitations and restrictions imposed on the prototype. It deals with issues of rollout and pricing, both in the context of an energy utility installing set top boxes for the sole purpose of monitoring energy, and for the provision of EEIS as additional services to a customer who already has a home gateway.

It is to be emphasised that the result of this project is not a polished commercial service, but a demonstration of each application as it is expected to work. The system is defined as a neighbourhood scale implementation of an EEIS and loading tests are performed with that scale in mind, but a full rollout is not covered in this project.

3.1 The System

3.1.1 The Proposal

A clear definition of the system to be developed is required at this stage. Both the number of households that will be provided with the service and the volume of data to be generated must be defined. It is therefore proposed that a prototype EEIS capable of serving some 10,000 residential households is to be created. Services will cover temperature, electricity use, gas use, CO detection and relative humidity in the indoor environment, and motion sensors.

The provision of this service will be through the Ericsson e-Services model, with e-Box home gateways and a generic model for sensor bundles. EnTrak will be used as the basic platform for the information management.

There are two primary objectives in the creation of a prototype service. One is to produce a working system containing all the equipment in the e-Services model, from sensors through to web server, for a single e-Box. The second is to run software tests and make simple and general calculations on the capacity and costs required to meet the demands for the households that are expected to be customers for the services.

These goals are expected to be complementary to the overall research objectives outlined at the end of chapter one.

3.1.2 Software Development and Testing

Given the flexible nature of the Ericsson e-Services model and of web-based services in general, the implementation of a simple example may be developed and tested in pure software. This was the case in this project, whereby the hardware components in the system were simulated in software and run as a 'virtual system', alongside the software components. Eventually the system was migrated to hardware for testing.

3.1.3 Components

A system comprises:

- **An e-Box (edge server/home gateway)**
- **Sensors, actuators**
- **An access network provider/e-Services centre**
- **An e-service provider**
- **Client PCs**

Just as each component may be simulated in the software model, a mix and match approach was made as to hardware migration. Components or even clusters of components were simulated as 'black boxes'.

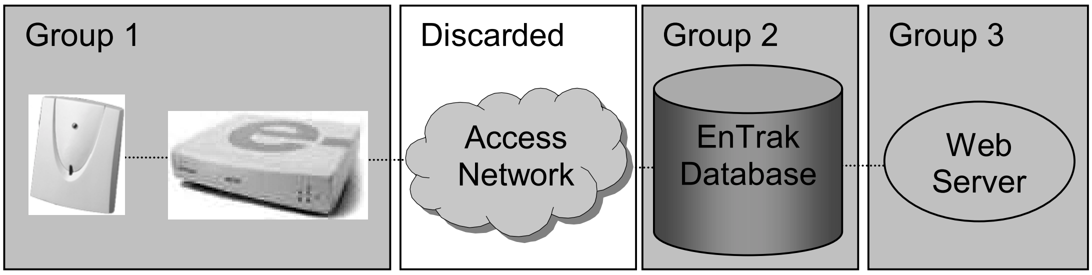


Fig: Grouping of Components for software test purposes

Each major component in the e-Services model communicates through TCP/IP. This allowed some flexibility in grouping or replacing components. It also allowed components to be represented as processes on a single PC by looping back the configured IP address.

Some components had been pre-configured to provide the requisite functionality. For instance, both the e-Box and sensors are designed to update themselves dynamically at start up. An e-Box boxlet previously developed by Strathclyde was used to query the sensors and forward the data to the EnTrak database. Such components were replaced by simple scripts for software testing purposes. The hardware only needed to be considered for installation purposes.

3.1.4 e-Box and Sensors

For our purposes, both e-Box and sensors may be regarded as a single unit in software, periodically updating the database with new data. In this project, this was replaced with a simple program, which read a data table, and updated the database continuously through the day at predetermined intervals. This simulated more precisely the updates from a single e-Box through the day.

A number of real-world readings were obtained from the Strathclyde University EnTrak database, enough to cover 24 hours of updates to the local PC database. These were read to a formatted plain text table, and a simple Java program was developed that could read the values from the text periodically, and update the local database. The text file could be edited to insert particular test data. Furthermore, the program was made scaleable so that multiple e-Box and sensor installations could be simulated at once.

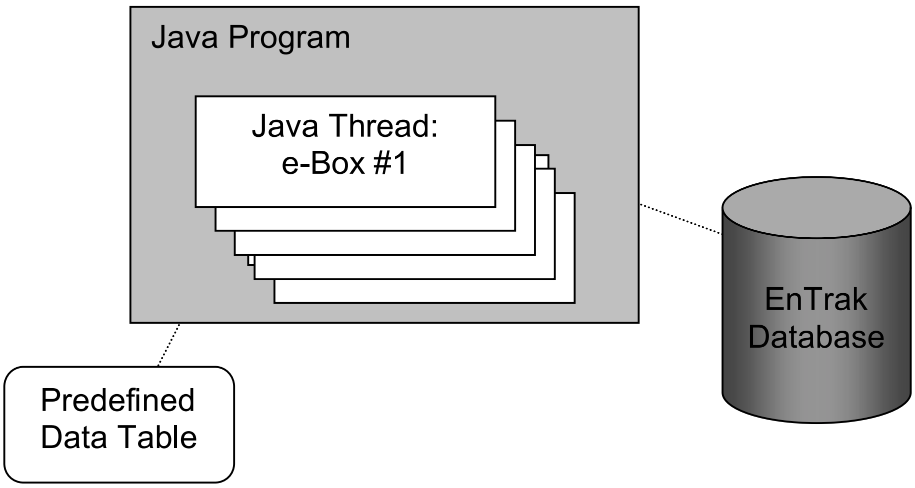


Fig: Java Program feeds a copy of EnTrak database

This multiple simulation is important in that it can give us an idea of how the system will perform under a certain amount of load. The simulation provided results that can be scaled to account for a neighbourhood e-Box programme. Alternatively, any number of home gateways may be simulated given a database server that is correctly sized. Although there is software available to simulate an e-Box in its entirety, it is not necessary in testing with this objective. Note that e-Boxes do not directly update the database in the actual system but data is routed through the e-Services centre.

3.1.4.1 Data Load testing with the e-Box simulator

The e-Box simulator was run on a home PC over a 10Mbps Ethernet connection to a server PC running a copy of the EnTrak database. Tests were run using a varying number of simulated e-Boxes with varying update times, updating to a Wintel Athlon 1Ghz server with 512Mb RAM. This was regarded as a base specification server for sizing purposes.

It is important to note the distinction between a single insert run many times in the same process and many connections running inserts concurrently. Concurrent connections raise the computational overhead for the server. Tests were run both from a single process and threaded to simulate concurrent connections, along with standard mySQL database benchmarking tests. These results could then be used to find a general relation between the three for prediction of far greater loads than could be simulated.

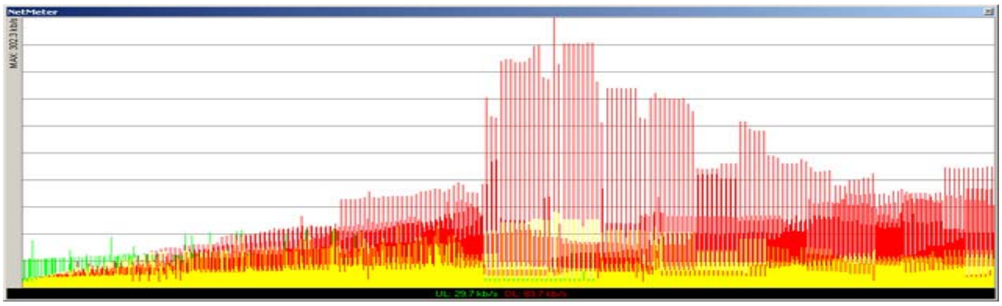


Fig: A graph demonstrating the start up of 200 simulated e-Boxes.

The graph shows the network activity resulting from the start up of 200 simulated e-Boxes. Green bars represent data uploaded from the server, red bars represent data inserted into the server and yellow represents the combination of uploads and downloads. The graph updates every second, values are in kbps, and the scale is in percentage of the largest reading. Note how more data is uploaded to the server at the beginning when the e-Boxes are establishing connections. The load increases steadily to a peak and then stabilises. The maximum throughput represented in the graph above is only about 300kbps. The graphs depicting lower network activity are shown here as they best convey the visible trends.

The test was repeated with runs of 500 and 1000 simulated e-Boxes. This resulted in throughputs of about 400kbps and 900kbps respectively. In short, a mid-range desktop

PC running mySQL was more than capable of handling a load of 1000 e-Boxes with a data update frequency far in excess of requirements.

Further tests were run with update frequencies in the half-hour range. With updates performed every half-hour, the number of e-Boxes could be increased and the hardware could easily accommodate 10,000 clients. This demonstrated that a reduction in the frequency of data updates could have a large effect on server sizing, and was taken into consideration when proposing the measurement frequency for the EEIS system.

Discussion of data collection frequency from a view more focused on built environment monitoring requirements is presented elsewhere in this chapter.

Load testing a simulated network of e-Boxes continuously inserting sensor data into the database is only half the story; our energy information service database must also answer specific queries from the web server for translation to graphical format. This will be addressed in a later section.

3.1.5 Access Network & e-Services Centre

The access network component is the section from the broadband connection in the house to the e-service provider's database, and the e-services centre is a central facility for co-ordination and maintenance of the many e-Boxes in the e-services model. These components are the responsibility of the telecommunications provider and e-service administrators respectively. Although central to the business model of online energy services, these components are essentially transparent to the operation of these services. It is therefore discarded from the software testing model. Although the access network need not be tested in detail, bandwidth issues may affect the services that are provided by the EEIS. A certain minimum bandwidth at all times is assumed for the purposes of testing the prototype services. T1 access is assumed for the server, and 512kbps broadband access for the e-Box. In practice, the bandwidth consumed by monitoring services on the e-Box will be well below this figure.

Despite access network issues being discarded for consideration in the software testing model, the final prototype tested on hardware did indeed function through the access network and an e-Services centre.

3.1.5.1 SQL Query Data Load testing

The way the load testing of the e-Box inserts into the database was carried out has been explained in detail above. Data queries from the web server must also be accounted for. Although this data load is intermittent, it comprises operations that must run concurrently with the inserts from the e-Boxes.

In order to simulate actual queries from the web server an example query was selected as being the most complex, and then run on a randomised time interval from a Java program conforming to the same model as the e-Box simulation.

Queries were run both on a random basis and clustered to represent periods of peak demand, i.e. evenings and weekends when more homeowners would be checking their households' energy consumption, humidity, etc. At all times the queries were run concurrently with the e-Box simulation. The results are as follows:

To represent 'normal use' 70 end users were simulated, making queries at intervals of 5 seconds, with a random interval between their start up.

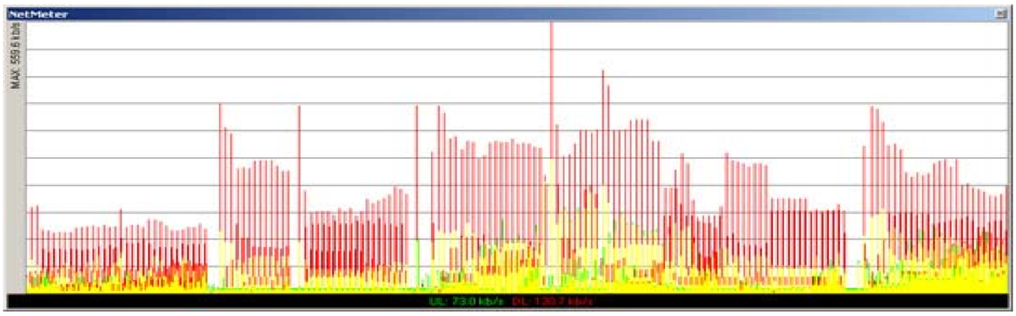


Fig: A graph showing SQL queries from the web server

The graph shows a system connected to 200 simulated e-Boxes. Queries from the 'web server' side begin just before halfway along the x-axis. As with previous graphs, green bars represent data uploaded from the server, red bars represent data inserted into the server, and yellow represents the combination of uploads and downloads. The graph updates every second, values are in kbps, and the scale is in percentage of the largest reading. Note how the green bars representing queries of the server increase after starting the simulation, but how the average data rate is only marginally affected. Note also that the majority of the bars representing kbps at any one second are no higher than 60% of the highest value – about 560kbps. This means that generally the load is only slightly higher than the 300kbps recorded without the web server queries.

Tests were also run to simulate peak periods of network activity: times when many residents would be accessing the web server at once. To this end, a full 200 end users corresponding to the 200 e-Boxes in the original test were simulated accessing the server at once, with a 1-second delay between queries. Note that these circumstances are unrealistic but are simulated in order to gauge the effect of loading on the server.

Note that although the loading is higher than would ever be expected relative to the number of e-Boxes, the relative bandwidth consumption is around double the bandwidth taken by the e-Boxes alone. All these figures may be extrapolated to size the database server relative to the number of customers provided for.

3.1.5.2 Recommendations for Additions to Database

The prototype EEIS described here has limited regard for e-commerce issues and although it keeps a simple list of usernames and passwords it does not record the user details that would be expected of such a system.

Customer Data

As would be expected, the current EnTrak database structure has full support for describing the building addresses that would be required for each customer. It is a simple matter to create a table of customer data, including such fields as user id, customer name, password, and a cross references to tables for the building address and e-Box ID.

Billing Data

A fully functional EEIS would keep track of customer payments as well. A fully-fledged e-commerce site would include the facility to record customer's payments and to allow online transactions. There are many security and privacy issues to be dealt with as well; therefore, a full e-commerce system is considered to be beyond the scope of this project.

3.1.6 Web Server

The web server component provides the point of reference for HTTP queries from web browsers.

The web server itself makes SQL queries to the database and replies to HTTP queries directed at its IP address. It can therefore also be run on a local host PC or a dedicated server machine. This is the 'middle tier' in the J2EE application model.

3.1.6.1 J2EE Code Structure

In using J2EE, we seek to reuse explicitly code that has already been developed for the EnTrak GUI. The Enterprise Java Beans that we create cannot be instantiated in a window on the desktop but can store information, process it, interact with EnTrak's MySQL server, and return an image. Therefore, we use JSP to gather information from the user, store it in the Java Bean, tell it to make a MySQL query, and request an image from it when done.

There are cases where new services are required, which have no analogue in the current EnTrak GUI. In these cases, Java Servlets have been developed, which query MySQL and draw a chart. For reasons of consistency, it is suggested that this functionality migrate to a Java Beans implementation in the future.

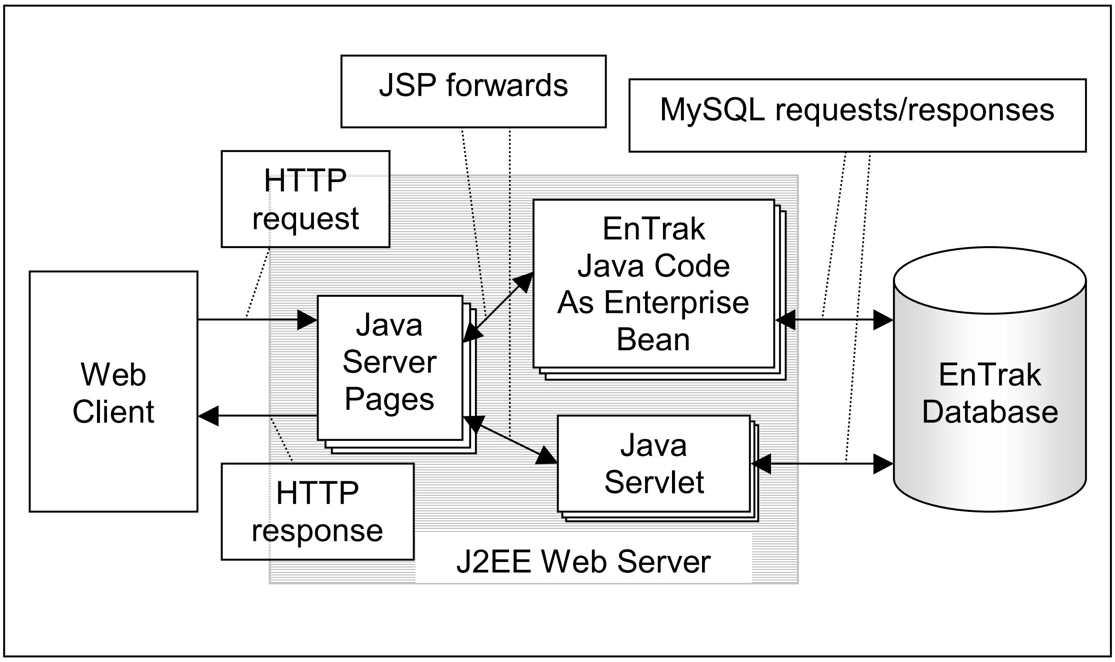


Fig: Simple J2EE code representation

3.1.6.2 Web Server Performance

The web server may be co-located with the database or situated on another machine. In order to evaluate the feasibility of co-locating the web server with the database a number of tests were run both manually and automatically.

The J2EE web server was co-located on the server machine with the EnTrak database. A number of web queries were made in order to force the first-time compilation of the JSPs. The continuous updating of the database from the simulated e-Boxes was put in motion.

One e-Service graph was chosen to represent the most computationally intensive SQL query, and was repeatedly called automatically from the client machine. It was found (as expected) that the full J2EE web service was significantly slower than the SQL query on its own. This was accounted for in server sizing in the costing exercise, which had a relatively minor impact on overall feasibility.

3.2 *Data Types and Frequency*

A luxury inherent in an always-on broadband connection is that data could theoretically be streamed continuously to the 'service centre' in real-time. However, the utility of doing so must be evaluated – there is little point in overuse of bandwidth if the data itself is useless detail. Therefore, a balance must be struck between frequency of update and use of information.

The EnTrak system will cope with varying data collection frequencies but focussing on indoor environment for any particular household may require reporting on a daily, hourly or minute-by-minute scale rather than the monthly scale often used by energy managers.

The range of data types is presented here with discussion on the data collection frequency of each.

3.2.1 Electricity Use

The electricity supply industry rarely requires metering on less than a half-hourly basis. Data on a shorter timescale has research applications in appliance scheduling, but such a scheme would perhaps be better suited to implementation on the e-Box as opposed to an online implementation. As such, it is beyond the scope of this project, and electricity use is monitored on a half-hourly basis.

3.2.2 Gas Use

The purchase and provision of gas is less complex than that of electricity; spot prices vary less, as gas can be stored more easily. Therefore, records of gas consumption on a half-hourly basis should be more than adequate.

3.2.3 Temperature

Although thermodynamic processes in the home are continuous, they generally take place in the realm of minutes rather than seconds. A sudden event such as the opening of a window in the home may cause short-term temperature changes but the utility of measuring such an event is suspect.

However, temperature does have a psychological factor that may make high frequency monitoring more attractive. Homeowners typically expect to be able to look at a thermometer (electronic or otherwise) and get an instantaneous reading. Providing such a low-latency application may serve to remind the user of the benefits they are receiving through their smart home programme. Should monitoring temperature on a short time basis prove too costly in terms of bandwidth and storage, a useful compromise could be to ‘loop back’ readings from the e-Box for the customer to read direct from their local network.

3.2.4 Relative Humidity

Relative humidity will change throughout the day as temperature differences between the outside world and the home environment shift, occupancy changes, and washing is dried. However, the use of humidity as a factor in mould prediction requires data gathering on a long term basis, therefore a sampling frequency on a half hourly basis should be adequate to detect average values.

3.2.5 Carbon Monoxide

Death due to carbon monoxide poisoning generally occurs at 4 hours after first exposure, at high levels. However, symptoms are progressive from a low level of exposure and the elderly and infirm are particularly at risk.

Dangerous time of exposure depends on concentration of CO in the atmosphere but BSI (and therefore legal) requirements state that a CO detector must alarm within 3 minutes at high concentrations of CO. Concentration of Carbon Monoxide is measured in parts per million. Margins of error are very low at room temperatures.

In order to prevent excessive use of bandwidth in the case of CO monitoring, it is proposed that the CO detection service monitor gas concentration on a half-hourly basis, but update with greater frequency once it reaches a certain threshold. An alarm will be raised should the levels become dangerous in the short term.

3.2.6 Occupancy Sensors

Occupancy sensors will typically be used for security and care applications for the elderly i.e. if a resident has not returned home within a certain time a care worker will be dispatched, or if motion is detected at an unexpected time of night the emergency services will be alerted. There are privacy and resource allocation issues with occupancy sensing so such a service should not be too intrusive or sensitive.

Occupancy sensors are expected to return a Boolean value – motion detected or no motion. Therefore, code on the home gateway will return a value only if there has been any motion over a ten-minute period, and it is a time when motion is not expected, or over a longer period when motion is *not* detected and it *is* expected. More sophisticated pattern recognition routines are expected to be used in the future whereby the system can distinguish between a resident's occupancy patterns and an intruder. However, at the present time a manually operated service must be proposed, whereby an 'alarm' notifies the operator of motion in the home at unexpected times.

3.3 Bandwidth Issues

Although the usage of a broadband connection for each home gateway will minimise congestion issues, an estimate of the bandwidth consumed by the example services has been made.

This bandwidth usage for each home gateway and estimates of web traffic are then used to determine the optimum size of the database server.

3.3.1 Bandwidth Utilisation per Home Gateway

This section gives a very simple estimate of the bandwidth used by the data generated by the energy services on the e-Box and transferred to the server.

The e-Box will generate half-hourly data on at least five parameters for transmission to the database. The half-hourly values may be transmitted separately or condensed into one transmission for conservation of bandwidth.

One goal of the smart homes project is to investigate the possibilities offered by an always-on connection, that is, new services that may be available through transmitting data at any given time. To restrict data to a regular timescale is contrary to this aim.

All queries inserting data into the database through the 'indoor environment' table will take up a similar amount of space, padded by the SQL query and the TCP packets themselves. A table entry takes up:

ref_ref	zone_id	date	time	ic_item	value
Char *(18 bytes)*	*Char* *(10 bytes)*	*Date* *(3 bytes)*	*Time* *(3 bytes)*	*Char* *(8 bytes)*	*Decimal* *(8 bytes)*

Table: the format of all indoor environment parameter records in EnTrak

Where ref_ref is the e-Box name, the zone_id identifies the zone within the house where the sensor is placed, date and time together constitute the timestamp, ic_item is the indoor climate sensor that gives the reading, an value is the reading itself.

3.4 Data Storage Capacity

Some consideration must be given to how long data will be stored. The data that is gathered can be separated into two categories; that which is useful in the long term, and that which is useful only on a short-term basis. CO detection and motion detection come into this second category. The majority of the data is monitored half-hourly and calculations can be made on how much data is amassed over time, with a random element for the data that is transitory and has no fixed timescale.

All professionally maintained databases will be backed up on a regular basis, so that information is not lost in a crash or blackout. Short-term records will therefore survive on the backup media whatever their lifespan on the server. However, long-term data must be available to the customer for viewing. It is proposed that half-hourly data is consolidated into daily and monthly data on a progressive basis, with an availability trail of at least a month in the case of short-term data. This accords with the short-term and long-term monitoring services as described below.

10,000	**number of e-Boxes**
0.05	**KB per insert**
5	**number of parameters**
2	**updates per hour**
5,000	**KB per hour in the system**
3	**KB per second**
120,000	**KB daily**
0.12	**GB data to be stored daily**
0.84	**GB data stored weekly**
3.36	**GB data stored monthly**
40.32	**GB data stored yearly**

Table: Simple Calculations on Storage requirements

For 10,000 e-Boxes, the amassment of data is not large, given the cheap price of hard drive storage. It is estimated that data for some five years could be maintained online with ease. However, it has been seen that frequency of update times changes bandwidth requirements and storage requirements dramatically. For a larger number of e-Boxes or a shorter update time a definite strategy of data consolidation would be required.

3.5 *Specific Services*

A number of example services are proposed here, derived from literature review. The reasoning behind each service is given along with a brief technical description and any special requirements for the service.

3.5.1 Monitoring

Monitoring services are defined as those which gather data and display it direct to the screen with minimal interpretation. It is for the end user to analyse and interpret the information. Data is displayed in graph format and the user may select the data type, the timescale, and the data frequency.

Monitoring services are described here as separate although they are expected to be provided as a single service incorporating the features of both 'real-time' and 'long term' monitoring. Both monitoring e-services are new implementations for this project.

3.5.1.1 Real-time

This reports the data gathered in the very short term, providing an instantaneous snapshot of the status of the home. This may be used by the homeowner as a 'comfort message' – a reassurance that the environmental parameters in the home are as they should be. It also functions as an indicator as to how a user's habits in the home affect their environment in the short term i.e. opening a window or using many appliances at once.

Data is displayed as a line graph describing the continuity of the readings. The user may select a timescale for the display. The graph contains all values gathered in the timescale that led up to the present time. This means that the number of readings displayed on the screen may vary from time to time.

The graph will update itself on a continuous basis.

e-Box ID	An alphanumeric string representing the user's own e-Box.
Parameters	Typical parameters for the home will be: temperature, electricity use, natural gas use, CO gas detection, relative humidity.
Timespan	The user may view the data over a time span ranging from one minute to half an hour.

3.5.1.2 Long-term

Long-term monitoring displays gathered data on a timescale generally longer than half an hour. This allows the user to view a profile of the indoor climate parameter over the course of a day, week, or month. The application may also be used by utilities to calculate monthly usage statistics for dynamic metering purposes.

The data will be displayed as a bar chart if the scale is hourly, weekly or monthly. Shorter timescales are displayed as a line graph for easier identification of trends. The long-term display does not update itself on a regular basis.

e-Box ID	An alphanumeric string representing the user's own e-Box.
Parameters	Typical parameters for the home will be: temperature, electricity use, natural gas use, CO gas detection, relative humidity.
Ic_item	Sensor id.
Timespan	The user may view the data over a time span ranging from one minute to ten minutes.

3.5.2 Analysis

Analysis services provide automatic analysis of the raw data, providing value beyond mere monitoring. Analysis services are useful tools in estimating past patterns of consumption and planning for future use of resources.

3.5.2.1 CO Detector

Connected CO detection services have typically comprised a normal CO alarm connecting to the emergency services so that help may be called as soon as possible. This is a worthy cause, and any online service will naturally replicate this functionality. However, false alarms are rife in such connected detection services and the British Standards Institution has produced recommendations for minimum CO readings required to raise an alarm.

A CO detector must conform to legal requirements as a minimum. Therefore an online CO detection service must simply be a connected version of the original one – if an alarm is set off, the emergency services are called automatically through the Internet. However, it is also reported that serious health risk results from continuous exposure to lower levels of CO, particularly among children and the elderly. Such low levels may not be detected by a standard BSI approved CO detector device. The CO detector service will monitor such lower concentrations and present the findings in graphical format for a health and safety professional to interpret.

3.5.2.2 Mould Detector

It has already been noted that Glasgow housing is particularly susceptible to mould growth. An interesting 'rule of thumb' application has been developed from a Strathclyde paper, which can be used to determine whether a household has a tendency to form mould, and if so, whether said mould is dangerous to health.

From the two parameters of temperature and relative humidity, a point can be plotted on a graph of mould types, indicating a potential strain of mould. Should the house be poorly ventilated the mould could form, causing health problems amongst the elderly or other susceptible people. Note that although mould can sometimes form quickly, prolonged exposure to the correct conditions are required in most cases. Therefore, the parameters to the application should consist of average values as opposed to instantaneous readings.

As with the CO detector application, this service could become completely automated, with an alert being sent to an operator when the parameters had been within any particular area of the graph for a certain length of time.

3.5.2.3 Consumption

The energy consumption tracking service may be used in to ways: with or without a scope parameter presented. The version without a scope parameter gives energy consumption values for a single household depending upon the login id that has been given; the scoped version is for use by utilities to monitor overall consumption within a particular number of buildings. The energy consumption service was adapted from a pre-existing conversion of EnTrak services to dynamic html pages.

3.5.2.4 Comparison

A key analysis e-service that was identified in the literature review was the visual comparison between a household's energy consumption and the average energy consumption of other houses in the neighbourhood. This was found to be an extremely useful social motivator to induce people to conserve resources – they wanted to see themselves as more environmentally responsible than others did.

A comparison e-service is also useful to the Electricity Utility to determine whether energy consumption for any particular household is unusually large. Utilities may have schemes in place whereby they agree discounts on energy saving modifications to a home e.g. cavity wall insulation in order to reduce energy load. They may identify whom to approach to offer discounts using the comparison service.

The comparison e-service was devised and implemented specifically for this project. The user may select two 'scopes' for the comparison, one will be from a list of single dwellings and one, displayed as an average, will encompass the energy consumption of a particular number of households. Therefore, according to their access rights, a user may select only their own address and a neighbourhood average for comparison, or a number of addresses and collections of buildings. The Energy Barometer model was successful in reducing energy consumption because customers agreed that individual households could be identified in the comparison, leading to competition to be seen as the most energy efficient. Such a system may be easily implemented using the comparison service.

3.5.2.5 Classification

The classification analysis e-service is a port of the EnTrak classification facility. It displays a representation of the classification of buildings within a particular scope according to their energy consumption. This has applications in dynamic metering for Utilities, and echoes the comparison facility for homeowners – a homeowner can check their relative position in the classification scope they have chosen. If a homeowner knows their own energy consumption for a certain period of time, they can tell whether more homes are larger consumers than them or whether they consume more.

3.5.2.6 Gaseous Emission

The Gas Emission service takes energy consumption data for a particular scope and time and performs a simple calculation upon it to estimate the greenhouse gas emissions. The energy consumption total for a time period in kWh is multiplied with average figures for each greenhouse gas released. For instance, for the year 2000 the UK Department of Trade and Industry released figures that estimated 171 tonnes of Carbon were produced for each GWh of electricity overall. Gas produced 116 tonnes/GWh and coal produced 238 tonnes/GWh [7]. These figures may be used to estimate how much CO2 the household has used in electricity consumption.

Gaseous emission estimates have particular relevance to customers in industry in light of the Climate Change Levy (CCL). Past patterns may be analysed and the impact of new emission reduction schemes may be assessed. Emission tracking software helps accounting in support of the CCL and facilitates greenhouse gas emission trading for business.

Although there is a strong case for providing gas emission estimates for business, it is not commonplace to provide homeowners with this information. However, providing cumulative greenhouse gas emission totals for a household is a new way to bring home to a householder the impact their consumption has on the environment.

The national average annual CO2 emission from energy consumption is 8870kg per household. The readings from the graph can be further illustrated with comparative examples – a favourite is to use party balloons for comparison. 1 kg of CO2 will fill 73 party balloons at atmospheric pressure. The national average household CO2 emission will fill almost 650,000. This has a more visceral impact to a non-specialist than the raw figures themselves. The gaseous emission service was adapted from a pre-existing EnTrak service to dynamic html pages. The innovation in this service is in its application to the needs of homeowners as well as business.

3.6 Cost Estimates

A large factor in determining the feasibility of a project of this nature is in costing. Evaluating the full cost of implementing such a service and running it for a sustained period of time is a complex operation in itself. Nevertheless, a generalised costing exercise is presented here to give an overview of what must be considered.

It is important to remember that many businesses currently providing e-services of this nature are doing so at a loss in order to become competitive when broadband access becomes more commonplace. Health and safety utilities may be potential e-service providers, for which the investment in infrastructure represents a saving on full-time care of the elderly and vulnerable.

Cost estimates are given here both for a full neighbourhood rollout of e-Boxes and for the provision of e-services on the back of an already existing network. Broadband access is assumed, whether through prior communication & entertainment services or through subsidy. Broadband access costs, however, are not covered.

In all cases the full range of business costs are not considered – the venture is assumed to be undertaken by a successfully operating company, with the purchasing, technical, and financial economies that come with size.

3.6.1 Full Rollout

An estimate must be made in the first instance for installing the infrastructure for e-services where there was none previously. This will probably be the more common situation in the near future as home gateways have not yet penetrated the market to a large extent. A full rollout must be made for the express purpose of providing residents with energy services via the Internet.

The cost of providing each home with an e-Box and sensors, an e-service centre, and e-service provider is covered. Ongoing running costs and subscription costs are looked at, and the time required to pay back the investment costs is given.

3.6.1.1 Hardware:

This underlying hardware provides the basis for the service. Expenditure on hardware is not strictly cost but build-up of capital. Nevertheless, hardware is still subject to depreciation and maintenance. Hardware consists of the component local to the company, and that which must be deployed on site.

Local Hardware:

Server

Java's portability means that the prototype e-services web server and database may be run on either a Windows or UNIX system. However, most information professionals agree that UNIX systems provide the most security and reliability. Although Linux software is both free to use and open source, the UNIX systems provided on a business to business basis by software providers boasts direct support and accountability on the part of the sellers. The choice of platform is a business decision but the option of an entry level Sun server is considered here.

A Sun Enterprise 250 Server, with 400 MHz UltraSPARCII processor with 512 MB Memory, 36 GB Hard Drive, and a Solaris Server was chosen as a base spec server.

Database Software

A number of free and open source database implementations are available, such as mySQL, postgreSQL, etc. Support is provided on an informal basis on their respective web sites.

Web Server Software

The Tomcat software from the Apache Jakarta project is a servlet container and Java Server Pages implementation. It provides J2EE compatibility and may be run alongside the standard apache web server. Both are free, open source software, and available on a variety of platforms.

Customer Site Hardware:

e-Box

Ericsson e-Boxes will be used as the home gateway in this study. Each e-Box costs roughly €200 wholesale at the time of writing, translating to about £130 UK.

Sensors

Given the variety and complexity in the current sensor market, a hypothetical generic sensor set will be considered for costing purposes in this exercise. Prices for individual sensors will be combined with an estimated price for the basic connector to the e-Box. Prices for RF communication are also considered.

While various combinations of sensors may be used, a single sensor of each type is used for calculations here:

- Base Station: £100
- Temperature: £25
- Humidity: £25
- Motion: £25
- Electricity meter: £25
- Gas meter: £25

Although the sensors themselves may be relatively cheap, the available wireless technology to connect them is not. This estimate is based upon separate purchase of sensors and wireless mountings.

The overall cost of the package is estimated at £250. This brings the cost of e-Box plus sensors to £380/household.

3.6.1.2 Maintenance:

Once the service has been fully deployed, there is an expenditure on maintenance on an annual basis. This are expressed in terms of the tasks to be done.

Direct Labour Costs

The tasks to be performed divide into hardware and software maintenance. The tasks do not equate to any particular job but are calculated in person-hours. These sums account for accommodation, training and turnover etc.

Database Admin

Backups, addition of tables and administration of customer registrations. Tuning of database and server administration.

Helpdesk Support Provision

User support through the maintenance of a telephone/online help desk.

Code Maintenance

Bug fixing, web page updating, information updates, development of new services.

Installation and maintenance of sensors

On-site installation of sensors, and maintenance duties. Some of the sensors required in the service have a limited life. They must be checked and replaced on a regular basis. The estimate includes travel and materials. It accounts for a particular turnover of 25% sensor replacement annually, assuming the sensor life is five years and allowing for failures.

3.6.1.3 Revenue:

A commercial e-Services implementation will require adequate revenue from it’s customers in order to stay solvent. Given that the customer has already paid for a broadband connection, the subscription to the e-Services must be an amount that is reasonable to the customer, but adequate to cover costs. It must be low enough to be available to those suffering from fuel poverty, and not to negate any benefits from energy efficiency. Analysis has been carried out to determine the best price for the services – see appendix.

3.6.1.4 Break Even Analysis:

Given the costs and revenue that are presented, this section gives a simplistic estimation of the time in which an e-services operation providing service to 10,000 households can be expected to break even.

Repayments

$$A=Pi\,(1+i)^{n}/\,[(1+i)^{n}-1]$$

Where A is repayment amount, P is principal loan, i is interest and n is number of repayments. Interest rate is assumed to stay constant at 13% business rate and a ten-year loan is assumed as term of repayment.

Break Even Point

Break even point was compared against subscription costs to find the optimum solution. Using this formula, it was found that a service provider could move into profit in 3.85 years at the cost of a £12 monthly subscription.

BEP = (annual repayment + maintenance + other costs)/
(annual customer subscriptions)

This formula regards the service on an annual basis, working out the cost of providing the service for a year versus total annual subscriptions. The result is the number of years to 'sell' to break even. All costs are treated as fixed as a service is being sold.

3.7 Services Walkthrough

This section provides a walkthrough of how the system works in a particular instance, step by step. It covers installation, operation and results of the service.

3.7.1 Server Preparation

Once a user has signed up to the service, their details will be added to the database. They include a username and password, and the id number of their e-Box. This step is performed in advance of installation so that the e-Box can start updating as soon as it is configured.

3.7.2 Installation

The homeowner is assumed to have an operational broadband connection already. e-Box and sensors will be delivered and installed by an employee.

e-Box

The e-Box is a relatively small electronic component that can be positioned near the broadband socket as a traditional modem would. One network socket attaches to a broadband modem (supplied with the broadband service), and one to the home PC network, it there is one. It also requires a power supply.

Base Station

The base station is mounted in a plastic casing with an RS232 port, which connects with the port on the e-Box. It also requires a power supply. Placement anywhere near the e-Box should be sufficient but in some cases, it may need to be placed where wireless transmission is best.

Remote Sensors

The remote sensors are mounted in a tough plastic casing housing batteries and wireless equipment. They are best mounted wall hanging, in accordance with the previous discussion of sensor placement.

Registration

Once the other on-site components are plugged in correctly and switched on, the e-Box is then booted. After automatically identifying the network, it starts a web server that can be accessed from the local network to which it is attached. The installer will access the local network and e-Box web server from a laptop PC.

The page displayed from the e-Box allows the operator to specify an Internet address from which various additional drivers can be downloaded. The e-service provider's boxlet is one of these. Once the drivers are downloaded, a run command is given to them and they start up.

The provider's software on the e-Box will monitor the 'network' of wireless sensors and communicate with the central database, updating it on a half-hourly basis.

3.7.3 Operation

All of the e-Services in the suite may be run without user interaction. An energy provider may then monitor the results and contact the homeowner directly with advice about their energy consumption. The health and safety services also act as connected alarms, with no need for user operation.

Any end user operation of the services is by web page, accessing the e-Service providers's site to return their own information. Therefore, if the user has a home PC, they go direct to a particular web page to view their data.

Login

A number of non-secure information services will be available to the public from the web page, but in order to access their own energy data, the user must log in securely. A user id and password must be supplied before the user is redirected to a page on a secure connection. Once the user is logged in, they can log directly out of the system at any time.

Indoor Environment Monitoring

Once the user has logged in, there are three categories of services from which they may choose: monitoring, control and analysis. In this case, the user wishes to view the record of their indoor environment so they click on the 'monitoring' section, and then on 'indoor environment'. There are a number of parameters that must be set before the request can be submitted:

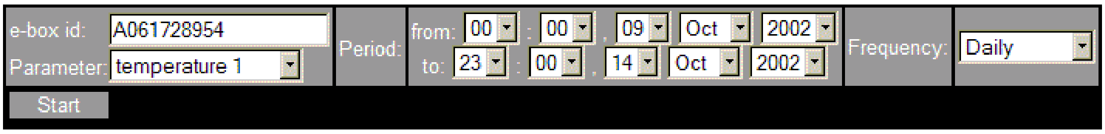


Fig: The parameters that must be entered

- The e-Box ID: An alphanumeric representing a particular e-Box. The user will only be able to see their own, but an energy manager could view many.
- The particular sensor they want to see the data for: there are a number of sensors, possibly more than one to cover each zone in the house. Each has a name by which they can be selected.
- The start date and time: readings from before this time will not be displayed.
- The end date and time: readings after this time will not be displayed.
- The timescale: data can be displayed monthly, daily, hourly and half-hourly.

Once these parameters have been chosen, the user clicks the Start button to draw a graph.

3.7.4 Results

Results are displayed in graph format with a scale appropriate for the parameter: i.e. indoor temperature ranges from 0ºC to 30ºC. The times of the readings are shown on the x-axis.

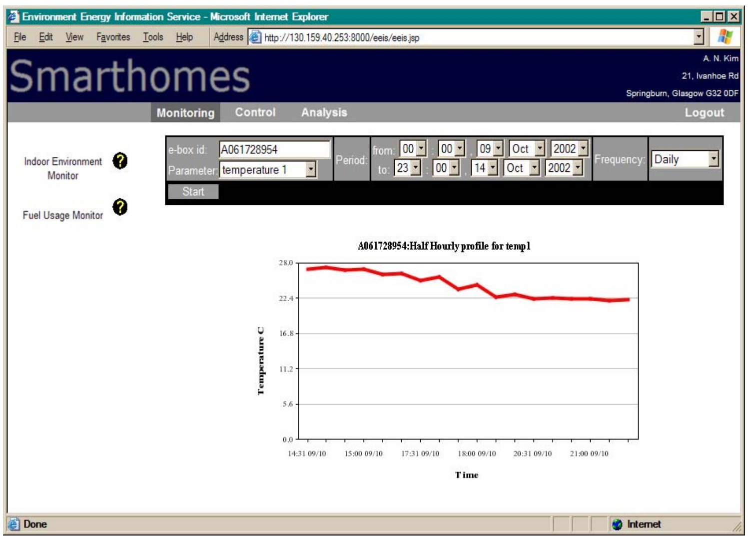


Fig: A temperature result set for an example e-Box

3.7.5 Developments

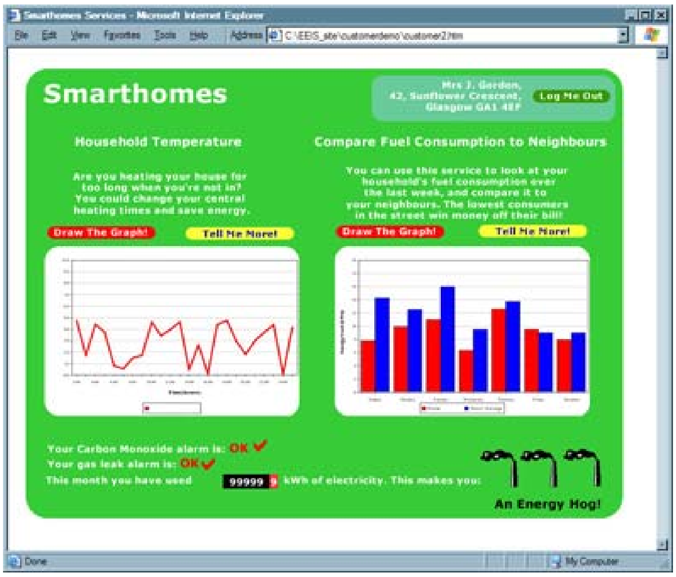


Fig: An example of e-Services as they could look

A number of schemes could be used to minimise inconvenience for the user; including organisation of e-service 'favourites' so that they are automatically displayed on login. A number of services may be displayed on screen at a time for comparison purposes, or just to provide an overview. Such service may contribute towards the useability of the service and make it more attractive to customers.

3.8 Chapter 3 References

1. MySQL
    a. *http://www.mysql.com*

2. Gnu's Not Unix – Explanation of open source software
    a. *http://www.gnu.org*

3. Java 2 Enterprise Edition
    a. *http://java.sun.com/j2ee*

4. The Java Programming Language
    a. *http://java.sun.com*

5. A good website on web page usability
    a. *http://www.usability.gov*

6. An Energy barometer for Sweden.
    a. *Westergren K-E. (1998): Proceedings from CIB World Building Congress 1998, Gävle, Sweden*

7. Carbon Dioxide Emissions and Energy Consumption in the UK
    a. *Department of Trade and Industry 'Energy Trends', March 2001*

4 Chapter Four: Conclusions

4.1 Problem Summary

The residential building is becoming more of a viable target for energy saving schemes as the new century rolls on, especially under the objectives of the UK Home Energy Conservation Act. Some 50% of energy consumption occurs in the built environment and businesses have already been targeted in government schemes in many countries. It is likely that they will continue to be subjected to further restrictions over time. Schemes for the home energy market must be more subtle than business oriented approaches. Energy savings must be encouraged without coercion or infringement of people's right to consume if they choose to do so. A key element in doing so is in education of the populace and their access to information.

Fortunately, an information revolution is well underway. The UK government recognises an urgent need for high-speed Internet connections in support of the UK economy and the broadband take-up rate is at an all-time high. Regardless of the short term politicking that is resulting from telecommunications companies seeking to maintain a monopoly on high-bandwidth access, we can expect a reasonably high coverage for the nation within the next five years. Once the early adopter market is saturated, new services will be required to persuade the general population that high bandwidth access is desirable. This chicken and egg situation is one that content providers are addressing at the moment. When broadband becomes generally available, low-cost non-entertainment services may be introduced for relatively smaller markets e.g. health and safety services for the elderly.

Therefore, we can see there are two distinct economic phases that must be addressed: the phase where energy and environment information services must justify the full expenditure on the equipment that is to be installed, and the phase where significant cost savings may be made by using a pre-existing network. Both phases will benefit from the other services that connection will bring: movies on demand, IP telephony etc.

The Ericsson e-services model is a way in which telecommunications companies are seeking to solve the problem of content. By embracing an open standards model, they open the services market for smaller third party operators. One such service area is energy and environment. This model provides an ideal framework upon which to deploy a suite of services, rather than facing the prohibitive cost of developing each component in the Internet service provider chain for the sole purpose of deploying energy services. Therefore, the economic situation whereby entertainment services pave the way for home automation and energy saving applications is mirrored in the technical implementation of e-services – energy services may be developed independently and deployed relatively inexpensively on a pre-existing platform.

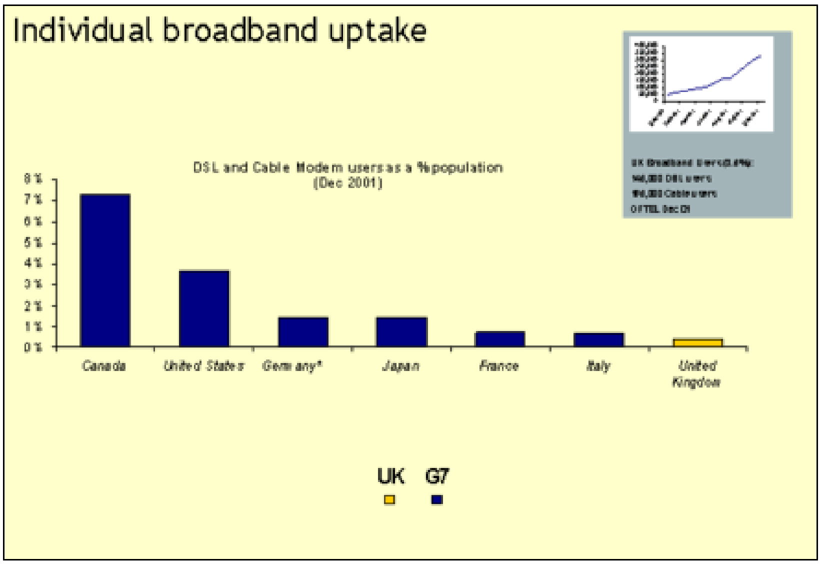


Fig: Broadband uptake in the UK compared to other countries

[Graphic from oecd.org]

Such is the premise; however, the e-services model and broadband service business models in general are being formed in advance of the capacity to implement them. Broadband is only available, even in theory, to some 66% of the UK population, and only 0.5% are signed up to a broadband provider [*1*]. In fact, despite high take up rates, broadband access faces a similar challenge in engaging the public awareness as does energy efficiency. Both are necessary processes in our transition to a sustainable economy and way of life.

Given the immaturity of broadband access in the UK, any energy services provided by broadband Internet must be proven both technically and commercially viable, as well as being effective in reducing energy consumption. There is a need for a prototype suite of working services, providing information that has been seen to be useful and effective in curbing energy consumption in the past.

4.2 The Project

The purpose of this project was to investigate the implementation of an EEIS in all of its aspects, resulting in a working prototype service. The prototype was to include each component in the Ericsson e-Services model and to prove that a third party provision of e-Services was workable at the present time. Another goal was to provide e-Services that were demonstrably useful in energy saving and health and safety applications.

For this project, a number of well-established services were derived from literature review, and some more innovative features were proposed as a demonstration of what could be done. The layout of the e-Services model was investigated and the separate constituent components were identified. It was found that e-Box maintenance and access network issues could be separated from the provision of a third party e-service. Each major component in the e-services model was addressed in turn: e-Box and sensors, energy information management database, and web server.

All the software platforms chosen for the EEIS were very portable, and could be deployed on a number of hardware platforms. This meant that development and testing of the dynamic web pages could be performed off site, and the development of software test tools replacing components in the e-services model meant that a full 'virtual' EEIS system could be implemented in software on a single platform if necessary.

The energy management system of favour in Strathclyde University, EnTrak, was evaluated for suitability as a basis for the energy information management at the core of an EEIS, and found to be a good proposition. Finally, the user interface of the services themselves was given consideration in order to tailor them to their audience, which may be new to the Internet in general.

Both the home gateways and sensors that were required for the Ericsson style implementation of an EEIS were available at Strathclyde University for demonstration purposes, example code was already available for deployment on the e-Box, and analytical features from EnTrak were available for porting to the dynamic web server system. Further services and test tools were created specifically for this project, and the web pages redesigned for their particular audiences. Particular services were selected for the EEIS with justification for their inclusion, and were integrated to produce a prototype system. Some services that were originally designed for energy

managers were found to have new applications for homeowners, which was out with their original target audience.
Once estimates had been made of the size of server required for a particular customer base, cost estimates were made to determine whether providing e-services was a viable proposition for energy utilities, small enterprise and health authorities. Both server sizing and cost estimates are notoriously difficult activities and the analysis presented here can only represent a general indication of cost. However, it is believed that a moderate service provided to 10,000 households would cost approximately £1,000,000 annually, without considering subscription fees. With consideration of subscription fees, the same coverage could be paid for within 30 months. It is noteworthy that only a model where e-Boxes are already in place and may be discarded from costs produces a reasonable price for the customer.
These estimates put the provision of an EEIS directly within the budget of an energy conservation authority or a local health authority seeking to implement home monitoring as a cost effective alternative to care homes for the elderly.

4.3 Barriers

Automated homes are at the cutting edge of technology and to seek to implement them is to investigate and to use immature technologies. This is counterproductive to the objective of creating a commercial, stable and economically viable product. The first to market with a new technology has the best chance of becoming market leader. It should be no surprise that to do so is difficult and involves the surmounting of various barriers.
Predictably, the major barrier in creating a commercially viable EEIS is in sourcing wireless sensors. The wireless element is paramount in our purpose of situating sensors correctly and invisibly to the customer. It is also the most cutting edge element of the home EEIS proposal. Although demonstration sets of ready-made wireless sensors are available for research purposes, there are no commercially available wireless sensors packages that may be used on a modular basis for our purposes. Any implementation of the system described here must either restrict itself to wired sensors placed sub optimally, or commission the production of wireless sensor sets on a commercial basis. It is worth noting, of course, that the lack of wireless sensor systems represents a great commercial opportunity for market dominance. This situation may well change within a year. New products reach the

market daily in response to demand and it is only a matter of time before well-packaged sensor suites become available for home PC use alone. The e-Box is well positioned for energy service operators to take advantage of PC style connections.

The demonstration version of the EEIS utilised a research suite of sensors sourced from Easy Living. Particular sensors were attached in a wired context to a data acquisition terminal and thence to the e-Box, if they were unavailable as a wireless package. For costing purposes, a price for such a wireless suite was assumed, taking into account the cost of wired sensors at the time of writing, and the cost of wireless technology.

Although the Ericsson e-services model is a spur to the creation of inexpensive, third party applications it is dependant upon the broadband infrastructure and home gateway deployment being present in the first place. Any such deployment in Glasgow cannot depend on the cost-reducing entertainment and communications services that are expected to form the primary application of an e-Box. Preliminary evaluation of the technical feasibility of deploying an e-service has been made in this project. However, this was from the perspective of implementing on a single e-Box only; a pilot project is necessary to evaluate issues of scaling and maintenance within the home.

This barrier was partially surmounted by the simulation of a system involving a large number of home gateways. During development and testing, simulation in software was used extensively in order to determine any particular component's capabilities. The behaviour of expensive equipment could be replicated in simulation on cheap PCs. This does not negate the need for real-world tests; rather it serves to prepare the central components of the system for them.

4.4 Benefits

Unless means are found of recouping the cost in the short term, rollout of home gateways and energy services with them will prove expensive. Energy management is generally considered to be a necessary evil by the population at large, a means of reducing expenditure rather than a wise choice or an act of service to society. Even those who claim to be willing to pay more for 'green' electricity sometimes do not in practice. It may prove impossible to change such ideas, but customers can be encouraged through a better understanding of how energy efficiency measures affect short-term expenditure once implemented.

All the same, energy saving information transfer and customer services have a rapidly expanding communications medium to utilize. The growth of ‘movies on demand’ and e-commerce will ultimately provide a useful platform for energy utilities and local health authorities on which to deploy services with little cost. Such e-services can ‘piggyback’ the demand for more immediately appealing services.

Even in the cases where rollout must be subsidised for the purposes of energy saving, the implementation of such a system may ultimately prove cheap, as further legislation requiring regulation of energy consumption is introduced. It can be expected that the overall cost of implementation will shrink in proportion to Moore’s law [2]. The further commoditisation of technology will bring a wealth of information within the reach of all sectors of society. It is to be hoped that this will bring an increased awareness of our surroundings when people can visualise the invisible processes of greenhouse gas emission and energy wastage. Freedom of information promotes education, and only through this can the actions of a nation be changed, in a fair democratic society. The vision pursued in this project is that technology can be harnessed to build a more sustainable world, restoring the balance that it helped to lose. Eventually the public will not see energy efficiency as a ‘necessary evil’ but as a means to contribute to the society we should all share.

4.5 Further Work

Given that the hardware base for environment and energy e-services is expanding all the time, it can be expected that new opportunities for services will be driven by hardware availability. Demand Side Management is an important area of research, and field trials in a domestic environment might bring to light new issues and perspectives. Studies on billing by reactive power may also be rewarding.

There are numerous opportunities for research on user interfaces in environment and energy information services. The format of standard HTML web pages, even if they are dynamic, can be restrictive. Download time concerns are valid in the implementation of Java Applets as user interfaces, but in a broadband environment, such download times would be negligible. It would be feasible to implement a dynamic front end that could create and combine reports on the fly, querying the database through the web server. Such a system would have more of the feel of a PC application with the convenience of Internet delivery.

There is need for research into how information can be presented to change the attitude of members of the public. We have seen how social competition can affect how homeowners use energy, but it is likely that other motivators can be harnessed in the conversion of the public into energy savers.

Implementing WAP pages for viewing on a mobile phone is an easy implementation in J2EE. Such features would allow greater mobility for operators and include segments of the population that have no means of browsing the Internet at present.

Chapter 4 References

1. UK e-Envoy Office
    a. *http://www.e-envoy.gov.uk*

2. Moore's Law page at Intel Corporation
    a. *http://www.intel.com/research/silicon/mooreslaw.htm*

5 Appendix A: Costing

A general costing exercise was carried out in the creation of the EEIS. This was in order to help play a part in the stated goal of the project - to evaluate the feasibility of providing an e-services suite in the Ericsson model. Due to limited data, costing can only be very general and is subject to significant error. However, even a general costing exercise can help determine the key elements that affect whether a business will be viable or not.

The major unknown in this exercise is cost of sensor hardware. Another flexible value which is to be determined is customer subscription price. In addition, there is the business model in which the cost of a home gateway is discounted from the analysis. From these three variables, we can construct three scenarios and determine whether pursuing any particular cost reduction strategy will result in a cheaper service.

First the cost of deployment for a full rollout of an e-services suite for 10,000 customers is given, then a visual analysis on subscription fees for the service, and analysis for pricing of sensors, and finally the effect on costs of a model where the home gateway is already present.

The initial evaluation gives a payback period of about six years. However, analysis of subscription fees for the service shows that comparatively small increases in fees drastically affect the payback time, and could render the service profitable within a year at its extremes.

Balancing customer expectations with the need to break even early will result in a price tag of £12-15 pounds monthly. Such a figure is probably far from commensurate with the savings that will be gained by energy efficiency, bearing in mind that an investment must be made in them as well. However, residents may accept paying this figure when health and safety services are counted.

A repetition of the exercise, regarding e-Box costs as nil showed that payback time could be significantly altered. The price point was around £10, which is probably more appealing to the customer. Price differences to sensors were found to have an effect roughly similar to changes in customer fees on payback time.

5.1 Full Rollout Costs

No. Customers:	**10,000**

Initial Hardware Costs	**£**

Sun Server (x2)	£14,400.00
Database Software	£0.00
Web Server Software	£0.00
Server Costs:	**£14,400.00**

e-Box	**£150.00**

Base Station	£100.00
Temperature	£25.00
Humidity	£25.00
Electricity	£25.00
Natural Gas	£25.00
Carbon Monoxide	£25.00
Motion	£25.00
Sensors	**£250.00**

e-Box and Sensor Installation	**£50.00**

Total Initial Hardware Costs: *(server+(no.customers*(e-Box+sensors+installation))*	**£4,514,400.00**

Ongoing Costs	**£/year**

e-Services Centre Subscription	£250,000.00

Customer Subscription	£120.00

Local Maintenance

Database Admin	
Salary:	£25,000.00
Office Overheads/ Support	£6,000.00
Training and Turnover	£3,000.00
Database admin (per person):	£34,000.00

Helpdesk	
Salary:	£17,000.00
Office Overheads/ Support	£6,000.00
Training and Turnover	£3,000.00
Helpdesk (per person):	£26,000.00

Code Maintenance	
Salary:	£25,000.00

Office Overheads/ Support	£6,000.00
Training and Turnover	£3,000.00
Code Maintenance (per person):	£34,000.00

On Site Repairs and Maintenance

Salary:	£25,000.00
Training and turnover:	£3,000.00
Sensor Replacement Turnover	2500
(number of sensors to replace annually - 25%)	
Transport	£2,500.00
(based on an average of 15 miles per task)	
(£1 per 15 miles overall)	
Materials	£75,000.00
(£30 cost of set of sensors for each replacement)	
On Site Maintenance:	£105,500.00

Database Admin/10,000 customers	£34,000.00
Helpdesk/10,000 customers	£26,000.00
Code Maintenance/10,000 customers	£34,000.00
On Site Maintenance/10,000 customers	£105,500.00
Total Maintenance per annum:	£449,500.00

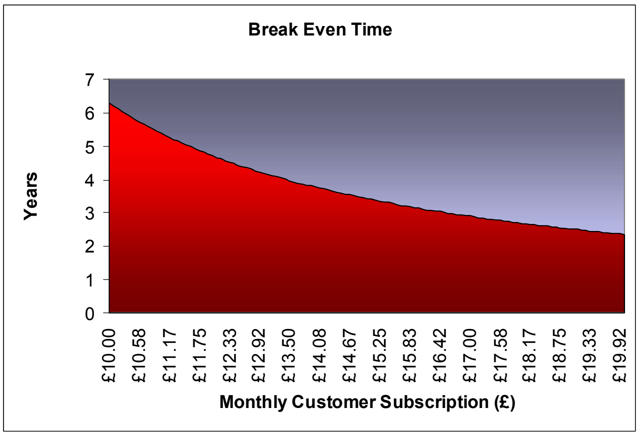
Business Costs	**£/year**
Insurance	£10,000.00
Taxes	25.00%
*(25% * profit)*	
Advertising	£3,000.00
Accounting and legal	£10,000.00
Depreciation	30.00%
Miscellaneous expenses	£10,000.00
Business Costs:	£33,000.00

Loan Repayments	
Principal:	£4,514,400.00
interest rate:	13%
number of repayments(annual)	10
Amount of Repayment:	£586,872.00

Annual Profit:	£997,971.00
*((subscribers*subscription cost)-(maintenance+business costs+repayment))*(100-taxes)*	

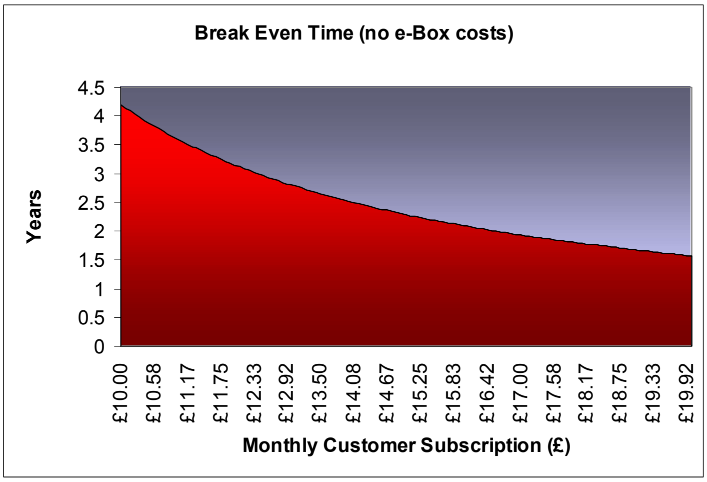
Break Even Time (years):	**6.29**
(initial investment/annual incomings)	

5.2 Break Even Time



This graph demonstrates the importance of the pricing of the customer subscription. The length of time to pay back the initial investment and become profitable varies dramatically between the price points of £10.00 and £20.00 monthly.

As we seek a low monthly subscription to benefit the customer and reduce energy poverty, we can tolerate a longer payback time, in the region of 3-5 years. This put customer subscriptions in the order of £12-£15 monthly.



Having considered the rollout of a system including an e-Box, the costs of a system without an e-Box were calculated. This greatly reduces payback time and brings the customer subscription down to the £10 monthly range within a reasonable payback time. It is proposed that this price point will be more acceptable to the customer and may fuel uptake of the service.