Integrated Information System Supporting Energy Action Planning via the Internet

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Abstract

Recent energy policy is designed to foster better energy efficiency and assist with the deployment of clean energy systems, especially those derived from renewable energy sources. To attain the envisaged targets will require action at all levels and effective collaboration between disparate groups (e.g. local government, private companies, research organisations, citizens etc). Such actions and collaborations will require energy partnerships with resource sharing, and communication systems that integrate distributed information and applications seamlessly.

The rate at which the Internet is increasing in popularity means that most organisations throughout the world will be networked in the near future. Today's database management technology has allowed the capacity for data storage to expand to an almost unlimited extent and distributed databases to be connected within networks operating at any scale. In addition, advanced software engineering techniques are enabling the establishment of on-line communication and distributed resource management.

This study established an Internet-enabled, Energy and Environment Information System (EEIS) for sustainable development support. The aim was to provide decision-makers with information on energy demands, supplies and impacts by sector, time, fuel type and so on, in support of energy action plan formulation and enactment. Essentially, the EEIS comprises a database and software agents capable of extracting and delivering 'data aspect models' tailored to different user needs. The EEIS is equipped with a consistent analysis system corresponding to various decision-making levels, from large-scale exploratory analysis (e.g. GIS and 3D data visualisation) to specified analysis (e.g. regression analysis, performance classification etc). The on-line integration of databases, modelling software packages and electronic communication protocols demonstrates the system connectivity potential of the EEIS.

As a specific implementation of the EEIS concept, the EnTrak system was developed based on Java technology. The applicability of EnTrak was tested using real data

collected at different scales: regional, municipal and institutional. The outcomes from these analyses demonstrate the potential for global support for decision-making at all levels.

Based on the capabilities of the EEIS as demonstrated in this study, it is envisaged that a collaborative system for sustainability between citizens, organisations, professional groupings and utilities could be established on a real-time basis. Such a system will enable a global analysis based on aggregated data derived from the on-line integration of distributed databases and allowing two-way information flow between decision makers and with the entities being managed (e.g. remote control of demand). Most importantly, such an on-line collaborative system can be implemented at low cost by utilising the rapidly growing Internet infrastructure.

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Chapter 1 Introduction

1.1 Energy Management and Sustainable Development

By January 2000, 84 countries, including most of the developed nations, had signed the Kyoto Protocol. The developed countries agreed to reduce their emissions of greenhouse gases to 5.2% below 1990 levels over the period 2008-2012. The Kyoto Protocol will come into effect after ratification by 55 countries, including the developed nations, who accounted for 55% of the global carbon dioxide emissions in 1990. Although negotiations are still underway over the actual details of the agreement, there is little doubt that it will be ratified. Consequently, reducing carbon dioxide emissions has become a key national energy policy issue for the developed countries (IEA 2000). The UK is one of the few developed countries to have published a clear strategy for delivering its 12.5% reduction target under the Kyoto Protocol. The UK Climate Change Programme (DETR 2000) includes policies expected to cut the UK's greenhouse gas emissions by 23% below 1990 levels by 2020 - almost double its legally binding target.

In the UK, national policy in regards to renewable energy is part of the planning process as outlined in Planning Policy Guidance Note 22, "Renewable Energy". The Government is proposing that regional renewable energy assessments should set the framework for a more strategic land-use planning approach at the regional level. Local planning authorities prepare their development plans within the framework of national policies and regional planning guidance. Development plans provide the basis for decisions on specific development proposals, which are not arbitrary. It is also important that operators prepare the ground with local authorities, environmental organisations and local people before formal planning applications are submitted.

The UK Home Energy Conservation Acts (HECA) of 1995 and 1996 required local authorities, as energy conservation bodies, to focus their attention on improving the energy efficiency of the housing in their district (DEFRA 2001). Authorities should be looking at measures which, when compared with the situation as at 1st April 1996, will lead to a 30% reduction. Substantial progress towards achieving this target is expected over a 10-years period. HECA also requires energy conservation measures such as information, advice, education (including staff training), promotion as well as making grants and loans and carrying out works.

Regional government, such as the Scottish Executive, is committed to action that will help to deliver the UK's Kyoto target and move towards the UK's domestic goal. Launched in August 2000, the Scottish Homes sustainable development policy seeks to improve the environmental performance and sustainability of Scotland's housing. The policy is aimed at those who receive grant funding from, and all organisations registered with, Scottish Homes. It is targeted at the wider construction sector with which Scottish Homes shares innovation and good practice. Some of the objectives of the policy are to

- improve the thermal performance of housing;
- reduce the need for physical resources;
- influence the location and mix of housing; and
- raise and improve consumer awareness.

In the private sector, business commitment to tackling climate change is growing in the UK. The climate change levy (Customs and Excise 2001) is a major new policy initiative, which will apply to energy used in industry, commerce and the public sector, with offsetting cuts in employer's National Insurance Contributions and additional support for energy efficiency schemes and renewable sources. In November 2000, DETR published a Consultation Document on the greenhouse gas trading scheme (DETR 2000). Emissions trading is regarded as a key part of the longer-term solution to greenhouse gas emissions. It can help to ease the transition to a lower carbon economy and will complement other measures in the business sector. Trading itself cannot deliver emission reductions. However, it can give companies and countries sufficient flexibility to deliver cuts in the most cost-effective way, and provides an incentive to seek out and develop new ways of reducing emissions.

Energy actions may be devised to encourage public organisations and companies to form partnerships to tackle the common problems associated with reducing energy use and gaseous emissions (Hertfordshire 2001, East Lindsey District Council 2001). Huskinson (1998) reported such an energy partnership between local authorities. The aims of the partnership were to deliver the outputs required by HECA 1996 and prepare to meet the energy demands of two million residents into the 21st century. To this end, there was a strong emphasis on renewable energy and a common strategy was prepared for all 19 authorities in the partnership. The project quantified the first year successes in both financial terms and reductions in CO_2 emission.

Jaccard et al (1997) have presented a Community Energy Management (CEM) approach that combines planning concepts, including complete communities and green cities, with energy management concepts such as energy cascading (e.g. recycling energy network, transformation etc), demand-side management and integrated resource planning. CEM was applied at the level of neighbourhoods, cities and even small regions in order to exploit the synergies between the urban design objective of minimising energy use and the associated environmental effects for a given standard of living. CEM is being applied to representative communities in British Columbia, Canada over the period 1995 to 2010. The aggregate effect has been a decrease in energy service costs and energy consumption of 18-30%, and in gas emissions (CO_2 and NO_X) of 30-45% in the first year.

An urban energy management scheme adopted to promote energy efficient practices within urban developments shows the significance of the partnership between public authorities and the private sector (Energy Efficiency Office 1995). Here, the approach to urban energy management is to

- o encourage lower infrastructure costs and quicker installation;
- o enable building users to improve control over operating costs;

- provide opportunities for innovative design using proven technologies (e.g. combined heat and power, photovoltaic panels etc) and techniques;
- encourage buildings that are healthy and comfortable through care in the design of heating , lighting and ventilation systems; and
- encourage higher quality environments around buildings.

As the benefits of results from urban energy management are brought to the attention of developers, building users, the letting agents and the owners, it is important to create more active involvement of the parties.

1.2 Decision-Making in Energy Actions

It is evident that plans for reducing gas emissions and ensuring sustainable development are associated with all actors, from end-consumers and the private sector, to local authorities. In order to achieve improvements from these plans, it is important to provide all actors with effective decision-making.

In the study on human decision-making and decision-makers, a most 'standard' view is the three-stage model (i.e. intelligence, design and choice) as defined by Simon (1977). Figure 1-1 shows this decision-making model and the role of instrumentation at each stage of the process. The intelligence phase consists of discovering that there is some problem or opportunity that needs to be addressed. After all, the decision-maker must first be aware of a problem before a decision can be made. Also, during this phase data about the problem or opportunity are gathered that will lead to a solution. During the design phase, the decision-maker attempts to use the data, and whatever other resources are available, to develop a number of alternative solutions to the problem. In the choice phase, the decision-maker selects one of the solutions to implement.

Simon (1977) also made the distinction between what he calls 'programmed' and 'non-programmed' decisions. Gorry and Scott-Morton (1971) define an unstructured problem as one in which all three phases of the decision process are unstructured;

clearly, a structured problem being one where all phases are structured. A semi-structured problem is one in which one or two phases are structured. This distinction is normally represented as a hierarchy of decision-making (Reynolds 1995).

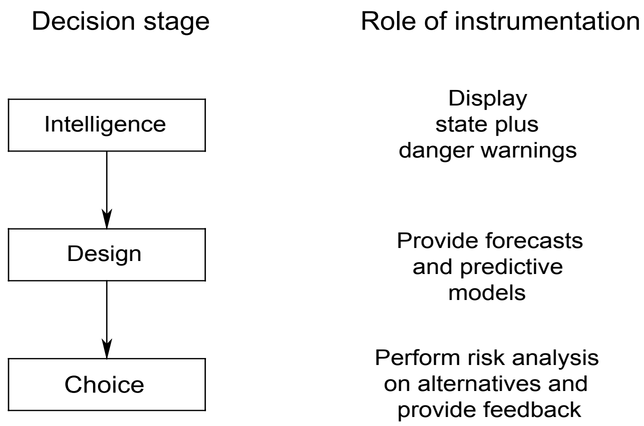

Figure 1-1 Model of decision-making (Simon 1977).

In general, a strategy is a plan, method or series of actions designed to achieve a specific goal or effect. The objectives of a strategy include finding problems, motivating actions, communicating with relevant resources, making targets and solving problems. Tactics are the actual ways that the strategies are executed. As described in Table 1-1, strategic decisions are associated with long-range and long-lasting impact so that upper level managers are usually involved.

Table 1-1 A hierarchy of decisions (Reynolds 1995).

Level	*Characteristics*
Strategic	Not routine Unstructured (non-programmed) Long-range, long-lasting impact Upper management
Tactical	Not routine Semi-structured Intermediate, medium-term impact Middle level manager

Operational	Recurring Structured (programmed) Immediate, short-term impact Delegated to low level managers

Tactical decisions are made for achieving the goals established by strategic decision-making. Operational decisions are subjected to tactical objectives. Therefore, a strategic goal cannot be accomplished without successful fulfilment of tactical objectives acquired by carrying out routine operations.

At the local, institutional scale, a policy for energy and environment is formulated by combining long-term goals by top managers, mid-term objectives by middle managers and short-term targets by operational staff (DETR 1996). For example, the long-term corporate goal might be to implement actions that are economically feasible to reduce energy consumption, to minimise CO_2 emissions, to minimise environmental impact, to promote use of sustainable energy resources and use renewable energy where possible. The medium-term objectives are more precise than the long-term goals. For example, they could be

- to reduce environmental impact of fuels by reducing the emissions of CO_2 by some percentage over a given period;
- to reduce the consumption of energy by a prescribed amount over a given period;
- to monitor and evaluate performance levels;
- to increase staff awareness and motivate staff to use energy efficiently;
- to provide regular management reports on costs and performance;
- to report performance changes and improvement annually;
- to procure energy efficient design of new buildings;
- to improve the energy efficiency of existing buildings;
- to identify all cost-effective energy efficiency measures; and

- o to conduct site energy audits.

The short-term targets will need to accommodate changes such as smaller premises with more staff per unit area, or even changing the means of measurement.

At the regional or national scale, while policy-makers act as decision-makers at the strategic level, energy managers are involved in a series of strategic and tactical decision-making when carrying out their routine work. Developers and planners are likely to act at the tactical level when implementing a regional energy strategy. They pay attention to the energy efficient plans defined by the energy and environment policy. Building designers often have to undertake an appraisal of the design options for new-build or refurbishment to improve the performance to a level that meets the target of the energy action.

From the viewpoint of citizen involvement in energy actions, it is necessary to change the energy consumption behaviour of consumers. It is generally known that increasing consumer's energy awareness leads to reduced consumption. Wilhite and Ling (1995), for example, reported the result of a three-year investigation of the relationship between billing information and household energy consumption. The experiment demonstrated that better billing feedback leads to a more energy-conscious consumer, one who is better equipped to make informed decisions about how to use energy in the home. Without extensive training or major technical innovation, the straightforward feedback techniques (e.g. past-use comparisons) had a strong impact on energy consumption: more informative bills resulted in energy savings of about 10%. This implies that citizens should be engaged more actively in a national strategy for energy management. They may play the role of a decision-maker at the operational level in terms of a national scale energy and environment policy.

As described, decision-makers including policy makers, energy managers, planners, designers, or even individual citizens will make different types of decisions according to their position. In terms of sustainable development, a set of strategic, tactical and operational decision-making steps must take place at all scales, from institutional to the local and national. Therefore, it is significant to support decision-makers at all levels in a coherent way to achieve effective aims in energy action.

1.3 Recent Trends in Decision-Support Systems

Decision-makers can be supported by tools with specific and well-organised information; such tools are able to deliver informative material to their users through appropriate data processes and understandable forms. The initial tools for decision-support for energy management were single task oriented and relatively simple. For example, a spreadsheet developed in-house may be used for analysis purposes, working from manual meter readings and other relevant data. Such analysis typically resulted in a simple graph to express performance. Later, stand-alone PCs were used to produce the analysis charts, which were originally designed for use by energy managers, more rapidly.

A Monitoring and Targeting (M&T) system is a traditional tool of energy management. An M&T system typically comprises three interrelating functions: for monitoring, prediction and targeting (DETR 1998a). Some parts of the M&T system automatically record and monitor energy consumption. These monitored data are then analysed to highlight any deviation from normal behaviour based on historical trends and patterns. Some statistical models are adopted to provide energy predictions. On the basis of these predictions, realistic reduction targets can be set. There are a wide range of M&T systems applicable to sites with a large number of meters (DETR 1998b) through to complex, multi-site operations (DETR 1998c).

As the methods of energy management have improved, and computer technology has advanced, the energy management sector has been equipped with ever more sophisticated IT systems that provide a comprehensive method for quickly and objectively identifying energy improvements. Such decision-support systems have been exploited to undertake assessments of single buildings and multiple-building estates. Various tools are available for identifying energy efficiency measures, selecting minimum life-cycle costs, determining payback periods, and enabling users to prioritise retrofit options and compare alternative financing schemes (site funding, leases, loans etc) (EREN 2000).

A scenario-based analysis evaluates the design options for an energy system while forecast analysis predicts the possible energy consumption over a future period so that users can establish a target plan. For forecast analysis, statistical modelling (e.g. regressions) or simulation programs can be exploited. Simulation-based modelling allows decision-makers to make informed decisions through energy prediction and scenario-based performance assessment, while identifying the differentiating design parameters between buildings of similar type but of differing consumption. Clarke et al (1997), for example, have reported the application of detailed simulation tools for the assessment of options for demand reduction and renewable energy systems deployment.

A Geographical Information System (GIS) is often exploited to support the evaluation of the potential of new and renewable energy sources and a financial analysis of the required investments (Voivontas et al 1998). In a GIS database, information about geographic, ecologic, demographic and economic factors is combined to yield a map representing an overall index of potential for new or renewable energy development. Jones et al (2001) developed the Energy and Environment Prediction (EEP) model as a city-wide environmental auditing and decision-making tool for use by planners. The EEP program is based on GIS techniques and incorporates a number of sub-models to establish energy use and emissions produced by buildings, transport systems and industry. It can be used as a planning and policy tool that will allow local government to select sites for development and improve the building stock that is already present. Likewise, Fragniere et al (1999) have presented a regional energy-environment model linked to a GIS interface that allows the decision-maker to assess the impact of energy policy choices on air pollution and on population exposure to health risk factors.

Meanwhile, energy and environment models have been developed through various techniques that use interrelated data, relating to the demand and supply-sides, with communication to users through tools such as GIS. For example, GIS technology has been integrated with building simulation and renewable energy assessment programs (Clarke et al 1996). Such a combination makes it possible to examine the matching of demand and supply profiles by time, location and fuel type against deployment imposed constraints (e.g. policy factors such as community proximity and land designation).

In order to address large-scale energy and environment issues in an integrated way, the decision-support tools require the addition of analysis software, compatible data communication systems and database management systems allowing massive data handling. The EnTrack system developed by ESRU at the University of Strathclyde is equipped to undertake the constant monitoring and integration of information on property and renewable energy schemes, conducting trend analysis and assisting in the setting of targeting (Evans 2000). EnTrack was designed to be applied strategically to establish broad policy, or tactically to investigate particular design and operational changes. Coupled energy simulation tools are used to create virtual energy data in order to study future scenarios. To improve data exchange with other systems, an EDI data transmission capability was implemented for the import of utility data (Karatolios 2000).

Taking EnTrack as a reference point, the following deficiencies may be identified in relation to the construction of an integrated decision support system as targeted in this thesis:

- platform-dependency of a stand-alone software system that acts as a barrier to the construction of a collaborative network between different organisations;
- weak inter-operability in that the system interfaces are not able to make effective integration with third party components (e.g. analysis or modelling software packages, on-line data monitoring/control systems);

- lack of flexibility in that the user interface is not independent from the database system so that the requirements of various types of users cannot be readily supported ; and
- poor scalability in that the structure of the database system cannot handle disparate information sources within heterogeneous database systems and large volumes of data collected from a number of data sources in high frequency.

1.4 The Evolution of IT

Since the World Wide Web was opened up to the public in 1994, the growth of the Internet has exploded almost exponentially. The global online population grew to over 400 million by the year 2000 (Nua Internet Surveys 2001). This is almost double the number who had access in 1999, when 240 million people were online (IDC 2001). It is predicted that the number of users with permanent, dedicated Internet access will be over 1.17 billion by 2005 (eTForecasts 2001). Improvements in the communication network have also started to affect the business world. By 2003, 87% of all business transactions are expected to be carried out online (Nortel Network 2000). Europe will be the fastest growing region for e-business over this period with a projected annual growth of 118%.

Meanwhile, as more people go online and the volume of e-commerce increases, the applications served by the network will be more bandwidth intensive. Table 1-2 gives an estimate of the bandwidth required for optimum performance of some example applications. It is evident that as users move from today's commonly used applications (such as text email) towards applications such as video over the Internet, the bandwidth consumed will rapidly increase.

Table 1-2 Application usage with current and forecast bandwidth requirements for residential and business sectors in the UK (source Analysis 2000).

	Residential	*Small business Sites (<100 employees)*	*Medium business sites (100-500 employees)*	*Large business sites (>500 employees)*
Approximate number of sites	24,500,000	2,500,000	31,000	3,700
Typical bandwidth	Email, e-commerce (home banking, shopping), entertainment (video, music)	Internet, inter-site communication (collaborative working, video conferencing, file transfer), e-commerce, application hosting)		
Current typical bandwidth	<512kbit/s	<512kbit/s	0.5-2Mbit/s	1-2 Mbit/s
Forecasted typical bandwidth (2005)	<2 Mbit/s	2 Mbit/s	4-10 Mbit/s	6-10 Mbit/s

Companies and governments are currently making substantial investments in Digital Subscriber telephone Lines (DSL), cable, new fibre optics, wireless equipment, and hardware and software for networks. The deployment of broadband digital networks is the key to enabling new, advanced Internet applications globally. Ultimately, the increased bandwidth reduces the time for data downloads from minutes to seconds, which is the minimum goal for acceptable response times (Nielsen 2001). The number of European citizens subscribing to broadband is expected to rise to 27 million by 2005 (Forrester Research 2000).

For access rates up to 2Mbit/s, the forecast for penetration in the UK is provided by IDC (see Figure 1-2). The prediction is that DSL services will have the largest share of the market in 2004, followed by cable modem services, with fixed wireless access accounting for less than 6% of the total of 10.7 million mid-band access connections. Of the total connections, IDC estimate that 9.2 million will be residential - representing 37% of households - and the remainder business.

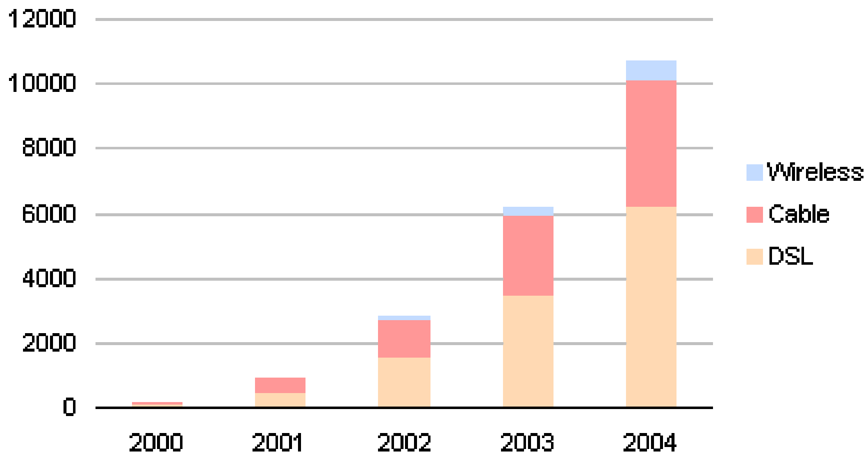

Figure 1-1 The UK mid-band access market (residential and business) by connections (thousands) (IDC 2001).

As well as the penetration of broadband users, another notable aspect in the growth of Internet infrastructure is the structural transmission of communication media. Young and Flanigan (1999) analysed the supply and demand for bandwidth and concluded:

"The future telecommunication environment will be characterised by low-cost, high-capacity international transmission facilities:

- surges of traffic will be readily accommodated because networks will have enormous capacity and multiple routes will be available;
- networks will be built on an IP-based infrastructure rather than traditional circuit-switched infrastructure; data and voice networks will merge - voice traffic simply being treated as packetised data;
- the cost of small amounts of bandwidth (such as individual switched phone calls) will be too low to justify the costs of billing each call;

- o the liberalisation of national and international telecoms markets will mean that accounting rates will disappear; buying bandwidth on demand will become typical; and
- o carriers will build networks that offer unlimited bandwidth at a fixed price between any two points; distance and geography will become irrelevant factors in telecom costs and pricing."

As predicted, while communication media will be integrated into a digitalised network, businesses will forge new relationships that will seem automatic - without paper or mail. One of the examples of business-to-business integration could be an application software service over the Internet. An application service provider (ASP) is a company that offers individuals or enterprises access over the Internet to application programs and related services that would otherwise have to be located in their own personal or enterprise computers. ASPs are expected to become an important alternative, especially for smaller companies with low budgets for information technology. Early applications tended to be generalised:

- o remote access serving for the users of an enterprise;
- o off-premises Local Area Network (LAN) to which mobile users can be connected via a common file server; and
- o specialised applications that would be expensive to install and maintain.

While ASPs are forecast to provide applications and services to small enterprises and individuals on a pay-per-use or period licence basis, larger corporations are essentially providing their own ASP service. Applications are being relocated from personal computers to special application servers that are designed to handle thin client workstations.

Recently, Internet-enabled applications have begun to emerge in order to engage citizens in energy actions. The Home Energy Saver (LBNL 2001) is designed to help consumers identify the best ways to save energy in their homes, and find the resources to make the savings happen. It computes a home's energy use on-line, based on methods developed at Lawrence Berkeley National Laboratory (Forowicz 1999). Providing a Web-based user interface and relevant database information, the program helps the user to estimate how much energy and money can be saved and how much pollution can be prevented by implementing energy-efficient improvements.

Westergren et al (1998) presented an approach called 'The Energy Barometer' to provide a solution to the combined problem of obtaining timely and reliable estimates of energy end-use consumption. In this study, Internet-based communication techniques (Lindfors et al 1998) were used to monitor building energy end-use at short-intervals. They describe how this new technology may be combined with statistical methods based on Energy Signature models.

Meanwhile, Katipamula et al (1999) predicted that as building automation system manufacturers continue to adopt open standards and provide interfaces to connect the control networks to the Internet, building managers, facility operators and energy service providers will have access to more sophisticated and automated software tools. This will enable them to manage distributed facilities more efficiently. Sarkinen et al (1998) explained how Web-based management for energy equipment can be implemented using Web techniques such as HTTP, HTML, Java and JavaScript.

While the Internet-based applications above hint at how current Internet technologies may be used for energy management, they are still bound to a certain aspect such as user type, dedicated industry, nature of service and information. There is no inter-connectivity between the various parties of the supply and demand side. The aggregation of extensive information associated with energy action planning is not dealt with. It is likely, however, that the rapidly growing Internet infrastructure will shift advanced decision-support systems toward a truly integrated support framework by which decision-makers at different levels may be brought together and connected to relevant informative resources on demand and in real-time.

1.5 The Future: An Integrated Information System Via the Internet

The present official energy statistics on energy end-use provides only crude and mostly out-of-date information. Such data are usually only available when the year has ended and the data has been adequately processed. The yardstick figures underlying Normalised Performance Indicators (NPI) (Energy Efficiency Office 1988) are, for example, published after a process of determination based on nation-wide energy data provided by a corresponding government agent, which is also unlikely to reflect specific situations in various areas. The act of continuous monitoring of buildings, which could cover either all or a statistically representative number of buildings, makes it possible to implement successful environment conservation programmes as well as to react quickly to trends in energy consumption.

There is, however, the limitation of data availability in collecting individual property energy statistics. Since energy consumption data are the property of consumers and utilities, they cannot be accessed without permission unless the property is owned by the organisation (e.g. local government). This presents a barrier to the accumulation of comprehensive data-sets. Evans (2000) described the difficulty in collecting each household's real energy data in an urban area and presented an alternative method to establish such high-resolution database.

Sletbjerg and Kristensen (1998) described the Danish Energy Agency's information system, Energy data which was established at the end of the 1980s; the system holds information concerning energy matters and associated environmental impact. Energy data's database contains information concerning energy about all buildings in Denmark (2.4 million) and approximately 7,000 energy planning zones. The information provided by Energy data can be utilized for a wide variety of purposes such as planning and analysis, designing energy plants, and administrative tasks. Information about energy and the environment can be calculated for energy plants, energy systems, consumers of energy, municipalities, and energy companies. Energy data was successfully used as a data source when a number of energy projects, analyses and follow-up activities were being planned and implemented. They also emphasised that well-functioning cooperation between central and local authorities and other actors in the energy field should be created.

Meanwhile, an energy partnership involving expert groups, building designers and local authorities may be established for a sustainable development project. The real time communication between partners will foster the synergy effect of the partnership. For example, embedding simulation programs in building design organisation has been attempted in order to foster an integrated approach (McElroy and Clarke 1999). Assessing the quality of the modelling results is then a significant issue. Hand et al (1999) emphasised real-time support for company-enabled simulation. However, the real time communication is often obstructed, as they are located in geographically separated places. It is hard for partners to share a common idea unless a truly integrated system environment exists in which the outcomes produced at each step of the project can be interactively exchanged.

Ideally, relevant information and knowledge should be shared by the partners in a network, such as utilities, their customers, local authorities and energy managers. Each partner tends to require the data possessed by the others. For instance, property data is likely to come from homes, utilities, organisations and local authorities. Fuel data can be read on site or collected from utilities. Local authorities generally possess geographical, environmental and political information. Consulting companies or research institutes have special knowledge of energy saving and new supply techniques.

The information resources in such an energy partnership could include building descriptions, metered data, weather data, energy reports and application programs (e.g. analysis tools, modelling systems etc). Usually, those who possess metered data are unlikely to be familiar with simulation modelling, and those who have the expertise in modelling will not have access to the metered data. Consider the requirements of the various decision-makers: it is suggested that collaborative working is necessary in order to tackle the technical barriers to obtaining high quality information resources.

To tackle the situation efficiently, a collaborative system is needed in which data sharing and communication can be carried out. The distributed resources such as databases must be connected within an integrated network so that the partners can share these resources. Figure 1-2 illustrates the parties that might contribute to, and draw from, an Energy and Environment Information System (EEIS) established to facilitate information sharing. The partners may then exploit remote databases or applications together with local information to support their decision-making via the EEIS.

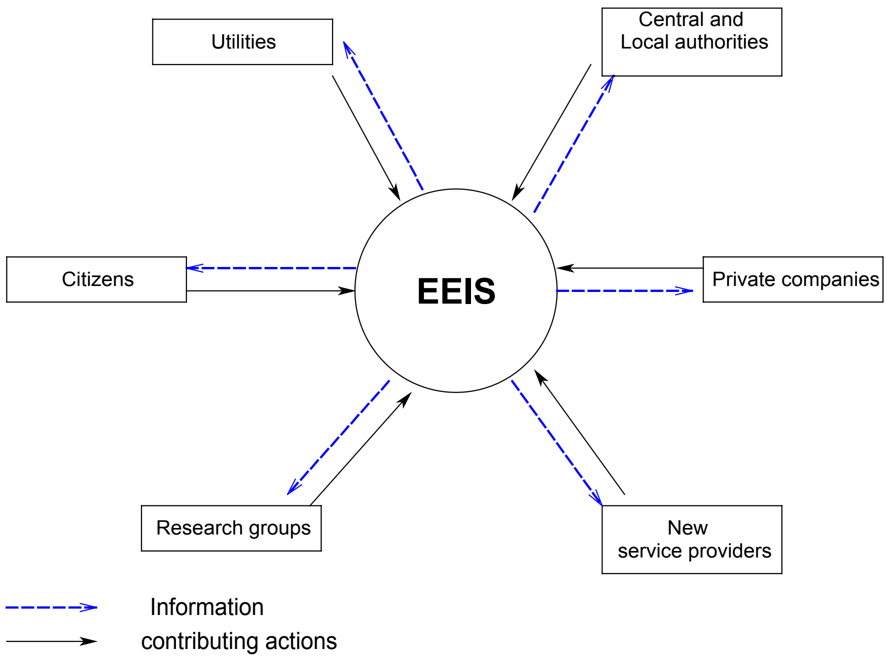

Figure 1-2 The role of the envisaged EEIS in the energy partnership.

In terms of its functional requirements, the EEIS must provide extensive energy and environmental analysis capabilities as well handle a huge volume of data. This will require multi-level tools, from a simple statistical assessment to scenario-oriented modelling (e.g. GIS, building performance simulation etc). Multi-media communication is another significant requirement for the next generation of energy and environment information systems. When transferring information, a well-designed display gives users a clear idea of the situation. In the energy management field, some notable display technologies have been proposed. Haberl and Abbas (1998), for example, adopted computer animation technology to deliver to building operators visual information on system performance, which would otherwise have been displayed through a series of complicated diagrams. A similar concept would be required within the EEIS. In addition, more interactive and experiential user interfaces would be engaged to create diagrams, graphs, reports etc. This requires an advanced software engineering approach to achieve the necessary level of flexibility and extensibility in constructing an integrated system of databases and analysis techniques.

At the same time, recent electronic service systems are expected to allow massive amounts of information to be delivered to the energy management sector by utilising real-time connections. For example, Ericsson, the telecommunications company, has developed a new e-service system (Ericsson 2002). An electronic gateway device called an ‘e-box’ is implanted in premises (e.g. houses, offices etc) and acts as a local network server connecting to the Internet. Using the e-service system, energy consumption and indoor environment data can be captured and delivered to energy service providers in real-time. The e-service system can work together with the EEIS establishing a communication protocol. The EEIS could offer a range of new energy services. Home temperatures and energy consumption can, for example, be constantly monitored, and building energy systems may be remotely controlled in a secure way. Appliances in homes or offices can potentially be connected to the EEIS via a smart chip that communicates with the outside world. Consequently, by coupling with this technology the EEIS will be able to encourage more active citizen involvement in energy/environment actions (e.g. monitoring real time energy/environment factors, encouraging energy motivation and providing advanced control).

As a decision-support tool for sustainable development, the EEIS caters for the requirements of individuals and organisations operating in the supply and demand side of the energy industry. The EEIS must therefore deal with extensive information held at distributed locations. While the information and analysis features of the EEIS should be capable of being shared between different organisations, the on-line indicators must also be delivered to non-traditional groups (e.g. citizens) to increase their awareness of energy issues. Such information sharing will help society to construct more collaborative energy partnerships. To manage complex information flows efficiently between partners, the EEIS must integrate these resources via seamless on-line communication. It is envisaged that the Internet offers the means to share such resources on-line and thereby support partnerships.

1.6 Research Objectives and Thesis Outline

This study starts from the hypothesis that advanced Internet technologies offer a solution for the integration and management of the EEIS. The objectives of this research are therefore to:

- identify appropriate techniques, which can be used to implement the EEIS;
- define the functionalities of the EEIS in terms of the nature of information, user types and analysis techniques;
- develop a prototype of the EEIS on the basis of technical specifications established via the above process; and
- verify the robustness and applicability of this prototype using real data collected at different scales.

The thesis contents are as follows.

Chapter 1 researches the context of an Internet-based approach to integrated energy and environment decision support.

Chapter 2 reviews the state-of-the-art in information technology and develops a specification for the envisaged EEIS from the technological viewpoint.

Chapter 3 considers the functional requirements of the EEIS and develops a specification from the user's viewpoint.

Chapter 4 uses the outcomes of Chapters 2 and 3 to establish the basic elements of the EEIS decision support system.

Chapter 5 uses the outcomes of chapters 2 and 3 to establish the specialist elements of the EEIS decision support system.

Chapter 6 transforms the basic and specialist elements to a working EEIS prototype.

Chapter 7 applies this prototype to three case studies designed to test the robustness and applicability of the approach at different scales.

And, finally, chapter 8 presents the conclusions from the research and identifies the required future developments.

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Chapter 2 Information Technology: the State-of-the-Art

In this Chapter, the key technologies for the implementation of the EEIS are reviewed and their applicability examined. The required technologies should be able to offer suitable tools to support the sharing of information and ideas among a scattered audience and to contain a sub-system for ease of administration and the enforcement of controlled access. The information system acts as a repository for large-scale and extensive information that is both accessible and retrievable and is equipped with proper security measures. It must also be an efficient distributor in that it allows authorised organisations and people to receive information in real time. The review of the state-of-the-art in information technology is focused on network programming, database systems, communication interfaces and user interfaces. The technologies reviewed are then integrated to form the architecture of the proposed EEIS.

2.1 Network Programming Technology

Apace with the evolution of the Internet, software technology is also evolving. Phipps (2000) describes this situation:

“In the 1980s software was about releasing the power of the underlying hardware and owning the latest drivers. In the 1990s, the focus shifted and software was about showing the power of the underlying operating system. In the new century, software is about revealing the power of shared standards. The world of shared standards requires five components:

- a networking layer;
- a mechanism for presenting solutions to users;
- a mechanism for creating software;

- a mechanism for formatting data; and
- a mechanism for security."

Phipps believes that all items except security are in place. The network layer is the Transmission Control Protocol/Internet Protocol (TCP/IP). For the Web, Hyper-Text Transfer Protocol (HTTP) is the solution. Java technology is the key to providing software for servers. The fourth piece to fall into place is the data segment, which is supplied by eXtensible Markup Language (XML), vocabularies that define the structure of various kinds of data.

In the following sections, the network programming technologies including the TCP/IP-based client-server computing model, Java and mark-up languages as user interface tools will be reviewed in relation to the technical requirements of the EEIS.

2.1.1 TCP/IP and the Client-Server Computing Model

The Internet began life as a research programme initiated in the early 1970's by the U.S. Defense Advanced Research Projects Agency (DARPA). The objective was to develop communication protocols that would allow networked computers to communicate transparently across multiple, linked packet networks (Vint 1998). The system of protocols that was developed over the course of the research effort became known as the Transmission Control Protocol/Internet Protocol (TCP/IP) Suite (IETF 1998). Today, the Internet is the common name for the world-wide network of computers, connected to each other in one way or another, using protocols from the TCP/IP Suite.

The TCP/IP protocols, and especially the Internet protocol, are independent of the hardware media. This allows the unrestricted exploitation of both existing and new digital transmission technology (Carpenter 1996). The openness of TCP/IP allows

- interconnecting the existing network media and the media yet to come;

- co-operation of applications on different networks and the overall exchangeability of information between applications; and
- vendor and network provider independence.

In TCP/IP based network computing, the client-server programming model is most popular. The term ‘client-server’ describes the relationship between two computer programs. A client is the requesting program or computer. A server is a program or computer that awaits and fulfils requests from the client. A given application in a computer may function as a client with requests for services from other programs and also as a server of requests from other programs. When the client and server components run in different hosts, the TCP/IP network provides a means of transporting information between them. This is illustrated in Figure 2-1. There can be multiple clients sharing the services of a single server, and the client applications need to be aware that processing is not being performed locally. Typically, multiple client programs share the services of a common server program.

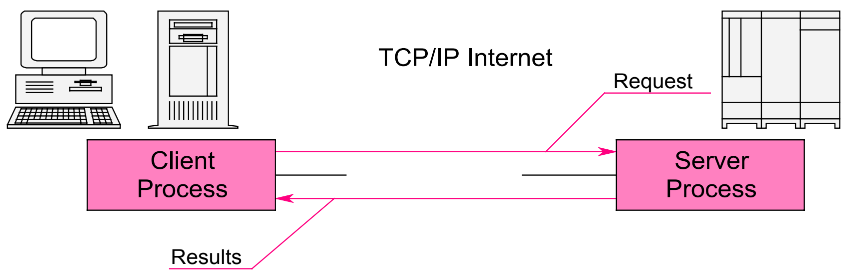

Figure 2-1 The client-server computing paradigm.

The flexibility and openness of TCP/IP made the protocol a well-defined international standard. It is clear that TCP/IP has the potential to provide a network infrastructure for the EEIS because various data communication channels need to be employed by the system. As the computing facilities and data resources of the EEIS are geographically scattered, and they may be shared by diverse users who are also spread out over the regions, the client-server computing model will provide foundational advantage in implementing the EEIS.

2.1.2 Java Technology

Java was introduced by Sun Microsystems in 1995 and instantly created a new sense of the interactive possibilities for the Web. Java is a programming language designed for use in the distributed environment of the Internet. Programs written in Java are portable within a network. The features of Java technology can be described with two parts: the client-side Java and the server-side Java.

In terms of the client-side Java, Java applets are small programs that run within the Java Virtual Machine (JVM) provided by the browser on the client side. They are embedded in an HTML page, downloaded to the client before execution, and run on the client machine providing graphical user interfaces. Applets may be the simplest way for people to exploit the functionalities and resources of remote server systems. There is no load on users (e.g. individuals computer owners within an organisation) to maintain the system's hardware and software, which might otherwise require effort and resources.

There are two main concerns regarding the use of applets: one is the time taken for downloading and execution, the other is the potential breach of security caused by running an unknown program on the local machine. While the applets should be designed to be as small as possible, the time issue predominantly depends on the communication infrastructure. As reviewed in the previous section, however, the infrastructure of the Internet is growing globally to become an alternative for mass communication. Ultimately, the EEIS is based on the expectation that the broadband communication network will eventually be all-pervasive.

Regarding security, Sun Microsystems addressed concerns by imposing certain restrictions on applets as shown below (Sun Security FAQ 2001):

- applets cannot load libraries or define native methods;
- an applet cannot ordinarily read or write files on the host that is executing it;

- an applet cannot make network connections except to the host that it came from;
- an applet cannot start any program on the host that is executing it; and
- an applet cannot read certain system properties.

Sun Microsystems introduced another concept called signed applets. A user may chose to trust a signed applet in which case the above restrictions do not apply (Sun Security and Signed Applets 1998). The Java Security Application Programming Interface (API) allows developers to incorporate both low-level and high-level security functionality into their Java applications. In order to establish secure energy information management, the applet-based component of the EEIS should be equipped with such advanced security systems because the information dealt with in the EEIS must sometimes have restricted access.

On the other hand, the server-side Java technology provides significant capability in integrating server-side resources and handling millions of users. In terms of software engineering, multi-connected network application systems are implemented in a three-tier client/server model. Figure 2-2 illustrates a three-tier application.

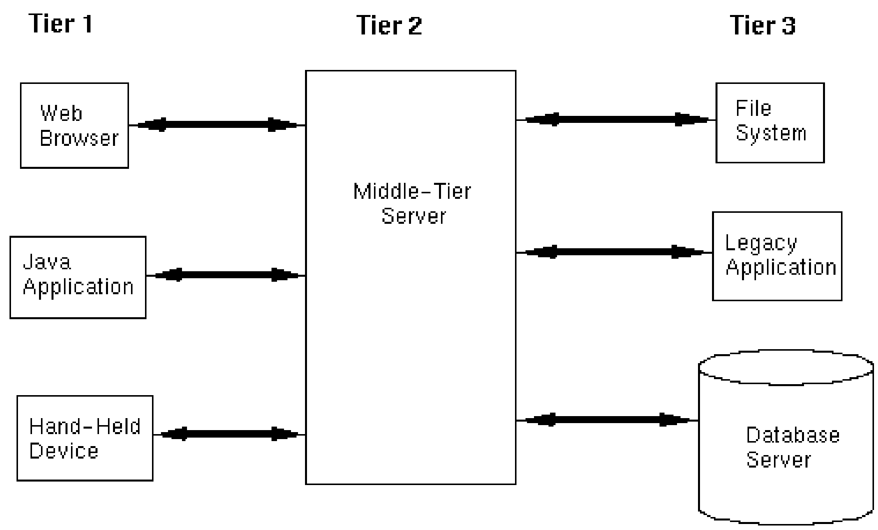

Figure 2-2 A three-tier client/server application.

Tier 1 is composed of multiple clients, who request services from the middle-tier server in tier 2. The middle-tier server accesses data from the existing systems in tier 3, applies program algorithms to the data, and returns the results to the clients in tier 1. A middle-tier server plays a vital role in a three-tier application. It handles requests from clients, shielding them from the complexity involved in dealing with back-end systems and databases.

The middle-tier server may support a variety of clients, such as Web browsers, Java applications, and hand held devices. The clients handle the user interface. However, they do not query databases, execute complex algorithms, or connect to legacy applications. They let the middle-tier server do these jobs for them transparently. Because the middle-tier server provides these services, the clients can be thin, simple and rapidly developed.

Java 2 Platform Enterprise Edition (J2EE) (SUN J2EE 2001), as a middle-tier server, provides the following system-level services:

- remote access to clients and back-end system;
- session and transaction management;
- security enforcement; and
- resource pooling.

Considering the features of the network software application, Java technology may be an effective way to implement the network-integrated EEIS because the EEIS should be able to communicate with different types of hardware/software systems. In addition to the portability of Java technology, the server-side Java technology (i.e. J2EE) provides the following advantages for the functionalities of the EEIS.

- It manages client access to the energy information database. The number of clients is essentially unlimited: home occupiers, local authorities, utilities etc. The information resources may then be shared by such users, sometimes simultaneously as long as hardware capacity permits.

- It renders it possible to design interactive Web user interfaces with dynamic content: a client's own data (e.g. energy use profile) may be obtained in real time and displayed alongside comparable data from other buildings of the same type. It also allows customisable information delivery depending on the user types. It provides information security. The data, generally confidential, is managed at the server side, and user access can be controlled by an authentication and authorisation system.
- It handles multiple database connectivity. The databases involved in the EEIS are likely to be distributed and located remotely; they must be integrated whether or not their hardware/software systems are compatible.
- It has the potential to accommodate advanced energy services. For example, remote energy simulation may be implemented based on legacy modelling applications.

2.1.3 Mark-up Language-based Interface

Most documents on the Web are stored and transmitted in Hypertext Mark-up Language (HTML). HTML is a simple language well suited for hypertext, multimedia, and the display of small and relatively simple documents. HTML is the set of mark-up symbols or 'tags' inserted in a file intended for display on a World Wide Web browser page. Because both the tag semantics and the tag set are fixed, users can easily create the documents. HTML is a formal recommendation by the World Wide Web Consortium (W3C HTML 2002) and is generally adhered to by the major browser developers. User interfaces with HTML are simple and easy to implement, which delivers informative materials from server-side to user (client-side) connected by the Internet.

Whereas it is accepted as the most popular format for network-based user interfaces, HTML has limitations in terms of extensibility, structure and validation; issues that become more critical as the quantity of information on the Web increases and the demand on network-based applications becomes more complicated.

- Extensibility: HTML does not allow users to specify their own tags or attributes in order to define parameters or otherwise semantically qualify their data.
- Structure: HTML does not support the specification of the deep structures needed to represent database schemas or object-oriented hierarchies.
- Validation: HTML does not support the kind of language specification that allows applications to check data for structural validity on importation.

Alternatively, eXtensible Mark-up Language (XML) is a flexible way to create common information formats and share both the format and the data on the Web, Intranets and elsewhere (W3C XML 2002). Unlike HTML, XML is extensible. The mark-up symbols of XML are unlimited and self-defining, which is implemented with Document Type Definition (DTD). The DTD is the grammar for a mark-up language, defined by the designer of the mark-up language. For example, computer makers might agree on a standard or common way to describe the information about a computer product (processor speed, memory size and so forth) and then describe the product information format using XML. Such a standard method for describing data would enable a user to send an intelligent agent (a program) to each computer maker's Web site, gather data, and then make a valid comparison. Any individual or group that wants to share information in a consistent way can use XML.

The benefits from XML in the development of Web applications may be summarised thus:

- data integration from disparate sources enabling structured data from these sources to be easily combined;
- self-describing data contained in a wide variety of heterogeneous applications;
- local computation and manipulation;

- o multiple views of data; and
- o granular updates eliminating the need to re-send an entire structured data-set each time a portion of the data changes.

The XML Object Model allows data to be manipulated with scripting or other programming languages. By describing structured data in a simple, open, robust and extensible manner, XML complements HTML, which is widely used to describe user interfaces. While HTML describes the appearance of data, XML describes data itself.

XML is also a self-describing version of Electronic Data Interchange (EDI), an old data-exchange method that uses proprietary file formats and hardware (Peat and Webber 1997). The major problem with EDI is that it requires that two parties agree on file formats in advance. EDI must go through a strict standards process to describe the formats of the data to be received or sent. However, since XML is a self-describing language, the method of formatting the data is efficient and fast. Due to the flexibility of XML, a system can talk to almost any other system without concern over what is at the other end, which is something that EDI could not do.

In the proposed EEIS, HTML and XML can be exploited to create user interfaces tailored to user types. A user interface with HTML and XML can be a front-end to databases (or application packages) accommodated in the EEIS server-side, which makes it possible to control data access according to user authority levels. Meanwhile, since multi-media materials can be embedded in HTML-based Web pages, information can be delivered in an insightful way via the Internet. For example, geographic maps created with HTML and XML could provide the visually-interactive front-end of the EEIS to users such as energy managers, who deal with multi-site properties. XML may also provide a means to integrate different applications into the EEIS as it is expected to allow the EEIS to handle energy/environment data in different formats from various organisations. However, in order to implement such a seamless data transaction, a common data format must be defined in advance by relevant parties (e.g. energy/environment modelling packages, data monitoring systems, database systems etc), which may not be trivial. HTML and XML was used within the EEIS to implement the interactive scope map models described in Chapter 4.

2.2 Database Management Technologies

When it comes to handling large scale and extensive information regarding energy/environment issues, the deficiencies in existing decision-support system are mainly associated with the underlying data model and the capability to store and retrieve data. The DBMS of EnTrack is limited in terms of the amount of data that may be stored, the weakness of the primitive file structures and poor provision in the areas of concurrency and recovery. In fact, the directory of EnTrack contains about 1600 files resulting from the fact that not only has there been many changes over time leading to redundant files, but a number of database files are utilised to temporarily store data as they are manipulated within an application.

The file structure limitation affects performance during data retrievals and updates, especially when the number of records becomes large. Strachan (1998) pointed out that the constraints of EnTrack stem from its DBMS, which is relatively unsophisticated and corresponds to a single user system. Strachan also mentioned that it is inevitable that further separation of the data will be required to increase the flexibility of the data and reduce the need for restructuring. Increasing the flexibility of the system naturally causes a more complex data file structure. In conclusion, she recommended: “A strength of the application is its simplicity. In essence, it captures energy-related data and by manipulating it and presenting the results in various ways, provides useful practical information. The current data structure appears more complex than necessary due to a combination of files present which are no longer used and additional files used to help the application such as saving values for a search. However, it should be possible to streamline this and redevelop using more appropriate tools to allow the application to handle any size of dataset without worrying about performance.”

It is necessary to identify an appropriate data model to achieve the desirable efficiency. Database management techniques, including the relational data model and operation model for distributed databases, are reviewed to determine their applicability for the EEIS.

2.2.1 Relational Data Model

The relational model for database management was developed in the late 1960's by a scientist with IBM, E. F. Codd (Codd 1970, 1990). Codd's work is notable in two aspects: database design and the architecture of the DataBase Management System (DBMS). The relational model introduced the idea of data independence and mathematical set concepts as the foundation for the database architecture. DBMS software directly accesses the data files in order to manipulate them. In addition, the data is stored in records consisting of fields of individual data items. Data is kept in tables similar to an enormous spreadsheet that might have millions of rows and columns. Each column contains only one type of data. A row in a table corresponds to a record. The database can contain several tables. Programmers can readily merge tables, extract information from them and update them. An example of a table is shown in Figure 2-3.

Employee Table

SSN	FirstName	LastName	City of residence	Position
512687458	Joe	Smith	Howard	Manager
758420012	Mary	Scott	Losantiville	Manager
102254896	Sam	Jones	Paris	Staff
876512563	Sarah	Ackerman	Upton	Staff

Meta data

Data

Figure 2-3 An example of a table in a relational DBMS.

The user application asks the DBMS for the data or passes the data along to the DBMS for storage; the DBMS then accesses its own files to do the appropriate processing.

The details of how the data is stored on the server's disk are hidden from the user's application. Figure 2-4 illustrates the architecture of the relational DBMS. This architecture gives the DBMS more flexibility in sorting and presenting the data to the user, while hiding the actual details of how the data is stored and manipulated. Accordingly, the relational model both increases database flexibility and provides greater data security.

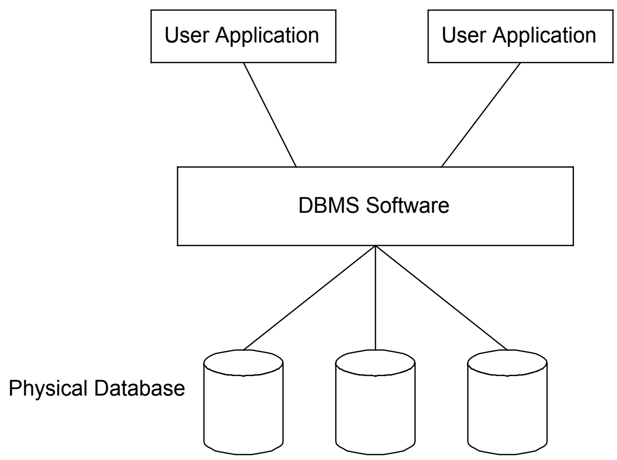

Figure 2-4 Architecture of a relational DBMS.

Connolly et al (1996) described the comparison of hierarchical, network and relational database systems. The difference stems from the data structuring capability. While a hierarchical DBMS naturally handles data relationships of 1:1, 1:N, it can hardly handle M:N. Network DBMS's can handle all types of relationship. However the usual physical structure requires navigation through the records. On the contrary, the relational system makes the data links through values of data items.

The common language for accessing a relational DBMS is the Structured Query Language (SQL). The interface between the front-end and the back-end is a specific application program interface (API) provided by the DBMS vendor. The operation of an SQL-compliant DBMS is typically implemented on the basis of a client-server model. Figure 2-5 describes the process of operation. The DBMS is a database engine located on a server that handles requests for data and provides data manipulation such as sorting and extracting. As data is stored on directly attached devices, the DBMS has rapid access to the data. The results of a request are then passed back to the client that made the request. Consequently, network traffic is reduced because the server only responds with appropriate data, not large blocks of data that the client would have to manipulate.

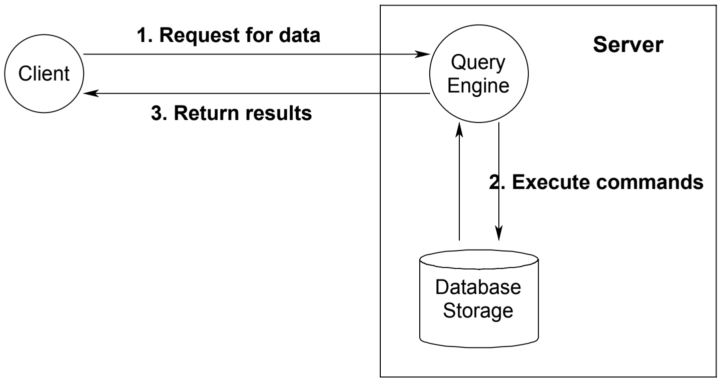

Figure 2-5 A typical client-server DBMS model.

Although there are several fundamentally different architectures for databases, relational databases are now almost universally accepted due to their flexibility. Most organisations possess relational DBMSs. It is significantly beneficial if the EEIS can achieve the integration of databases by adopting the relational database model. In addition, the table structure of the relational database makes it easy to import electronic data from different resources (e.g. field measured weather data, energy consumption data from utilities, outcomes from applying modelling software, heterogeneous DBMSs used in normal office work etc) without any additional hardware or software system.

2.2.2 Distributed Databases Operation Model

Ultimately, it is suggested that geographically scattered organisations in an energy-environment partnership should be integrated within a network system. There are two representative approaches in integrating scattered databases: a centralised structure and a decentralised (distributed) structure. A centralised system can be responsive to end-user needs in highly formalised circumstances and can offer superior security, data integrity and systems management. On the contrary, new demands on the existing system and the pressure of restructuring for a rapidly changing environment can best be absorbed by a flexible distributed system. An information system must reflect the informational needs, organisational structure, management philosophy and operational procedures. Considering the feasibility of realistic implementation, it is natural that the structure of organisations involved in the EEIS corresponds to the distributed information system rather than the centralised one.

As to the advantages of distributed systems, Errol (1996) stated:

"The main advantages of distributed systems is their ability to allow the sharing of information and resources over a wide geographic area, giving a systems designer freedom to optimise the placement of distributed system components such as data and processing."

Within the EEIS, the distributed information system model supports:

- Improved flexibility. Computers and other IT infrastructure components can be flexibly located at points within the network of the EEIS. Components can be added, upgraded, moved and removed, without impacting upon other components, to meet present and future needs.
- Local autonomy by allowing control to be defined where decisions are made. Local governments or companies generally have their own database for energy management. They may want to construct their own IT infrastructure for the EEIS (customised system) and may want to decide where resources (including manpower and IT infrastructure components) under their control are located. The resources in each organisation (or department) can be combined when judged necessary for mutual benefit.
- Increased reliability and availability. In a centralised system, a component (hardware or software) failure can mean that the whole system is down,

stopping all users from working. In a distributed system, multiple components of the same type can be configured to fail independently and provide a level of fault tolerance. Therefore, the failure of one component may isolate only one group of users.

- Improved performance. A large centralised system is likely to be slow as the traffic volume between users and the server grows. A service that is partitioned over many server computers, each supporting a smaller set of applications and users with access to local data, results in faster access (response times). Another performance advantage is the support for parallel access (updates and retrievals) to distributed data across an organisation.
- Security breaches are localised. In distributed systems with multiple security control domains, a security breach in one domain does not compromise the whole system. Each security domain has varying degrees of security authentication, access control and auditing.

There are various possible approaches to operating distributed databases, depending on the needs of the application and the degree of emphasis placed on central control versus local autonomy. One possibility is that a complete central database (e.g. a database operated by a qualified group) is maintained and updated in the normal way, but that local copies (e.g. data from local government) are sent periodically to remote sites, to be used for fast and cheap retrieval. Any local updates have no effect on the central database. The implication here is that consistency between all copies of the database at all times is not crucial. It may be enough to send new data to node sites overnight when networks are less busy. For instance, an energy service centre may construct a central database, collecting data from distributed local organisations, while these same organisations maintain their local databases contributing only some data to the centre. The energy service centre may then publish the shared information, administrating data access and ensuring retrieval efficiency.

Alternatively, distributed database development may involve the linking together of previously separate systems, perhaps running on different machine architectures with different software packages administered by various organisations. One possible scenario is that individual organisations manage and update their own databases for standard operational applications, and then that information is collected and aggregated for higher-level decision-support functions. In this case there is no single location where the whole database is stored. It is genuinely split over two or more sites. For instance, central government can access supporting information for energy policy making by simply connecting to a local government's database through multi-platform database connectivity.

A third possibility is that the database is designed to be distributed, and that all nodes in the network may in principle query and update the database at any location. Codd (1985) has specified a set of criteria to characterise a genuinely distributed system. While this approach may be the most sophisticated, it is a high cost approach because all databases involved in the energy partnership must be reconstructed. Unfortunately, there are few DBMSs for such a purpose commercially available today.

In the network communication, the most crucial requirement is availability of compatible protocols between the database management systems in disperse organisations. The middleware of an SQL-compliant database interface will allow the EEIS to operate as a distributed information system, thus contributing to the large-scale energy/environment partnership. The following section reviews the communication interface technologies.

2.3 Communication Interface Technologies

When an information system is coupled with external systems, an intermediate medium (e.g. a formatted text file) is usually used for data exchange. The intermediate file must be created under a set of rules that are known to both the sender and receiver. For example, utilities often provide their customers with an electronic data interchange (EDI) facility to deliver energy consumption bills. To import the data from an EDI formatted file, a parser is required to transform the data to a format suitable for the EEIS database. Although the EDI file can conform to a standard format, in practice the process of converting and reformatting the EDI data to suit the EEIS database is not trivial because there is no industry standard.

Karatolios (2000) made an attempt at data transmission from a utility's EDI format to the energy management system, EnTrack. As he experienced, unless the EEIS possesses EDI conversion, formatting and communication functionality, it has to obtain the data through bridging software that links the various applications programs within an organisation and maps incoming EDI messages to outgoing EDI messages. Because bridging software is specific to each organisation's programs, this software must also be customised. In other words, the data format from the bridging software is likely to be different depending on the specific bridging software being used. An EDI file parser cannot be generic.

In this context, data importing from various sources for the EEIS cannot be implemented unless a commonly acceptable data format dedicated for the EEIS is available. As advanced neutral media such as XML are expected to offer a better approach, the EDI file parser must be exchanged for either an XML/EDI parser or a pure XML parser to meet the requirement of the new electronic environment. However, this is a longer-term prospect and does not offer a practical way to handle multi-channel data transaction because it still needs agreement on the definition of data models between relevant industry partners.

The purpose of the present technology review is therefore to establish the best approach to data transaction and system interconnectivity within the EEIS. In order to make real-time data communication within the EEIS, it is important to establish a seamless connectivity between internal and external components, which requires communication protocols for on-line data transmission as well as the formatted data.

Communication interfaces should make it possible to manage new energy service systems such as remote energy meter reading, intelligent control and real-time energy/environment performance monitoring. There are two notable technologies regarding communication interfaces: database connectivity and electronic gateway systems. Based on these technologies, as elaborated in the following sub-sections, the architecture of the EEIS system interface will be discussed in Section 2.5.

2.3.1 Database Connectivity

The current trend is to provide so-called middleware products between the clients and server to allow users to access any back-end server using a variety of front-end applications. Middleware hides the differences between access languages and database APIs. Microsoft introduced its Open Database Connectivity (ODBC) standard, Borland developed its Integrated Database Application Program Interface (IDAPI), and IBM developed the Distributed Relation Database Architecture (DRDA) SQL standard. Recently, Sun Microsystems developed Java Database Connectivity (JDBC), which allows cross-platform database connectivity.

JDBC is an application program interface specification for connecting programs written in Java to the data held in various databases (Sun Microsystems 1995). Sun Microsystems designed JDBC to allow connection to any ANSI SQL-2 standard database. JDBC is similar to the SQL Access Group's ODBC and, with a small ‘bridge’ program, the JDBC interface can be used to access databases through the ODBC interface. Developers can therefore write programs designed to access many popular database products on a number of operating system platforms. For example, a program with a JDBC interface running on a Unix workstation could access an Access database running on a PC under the Microsoft Windows operating system.

JDBC actually has two levels of interface. In addition to the main interface, there is also an API from a JDBC ‘manager’ that in turn communicates with individual database product (direct JDBC) drivers, the JDBC-ODBC bridge, and a JDBC network driver when the Java program is running in a network environment. When accessing a remote database, JDBC takes advantage of the Internet's file addressing scheme and a filename looks much like a Web page's Uniform Resource Locator (URL).

Consequently, JDBC allows applications to share remotely distributed databases that are on different platforms. The communication and data sharing between the EEIS and remote-site data sources (e.g. weather stations, utilities, local governments, branch companies etc) could be implemented on the basis of the database-to-database connectivity. If the databases were inter-connected within a network, the EEIS could construct and administer these databases efficiently and economically. In addition, such database-to-database connectivity would give the EEIS an advantage in dealing with data transmission between organisations because there is no need to make any additional effort to transform data protocols.

JDBC provides users with Web-based front-ends equipped with a graphic user interface and simple calculation processes. There are two different approaches to accessing databases through Web browsers: applet with JDBC and server-host system such as JSP/Servlet. The JDBC (driver) deployment scenario is described in the top portion of Figure 2-6. The JDBC driver is downloaded with the applet embedded on the Web page. The applet can then use JDBC to directly query and manipulate the data source. Some advantages cited for this architecture include:

- no installation of the application and the database driver is needed on the client, they are downloaded on-demand; and
- any updates or revision of the application and database driver are automatically taken care of; and
- only a browser supporting Java is needed at the client end.

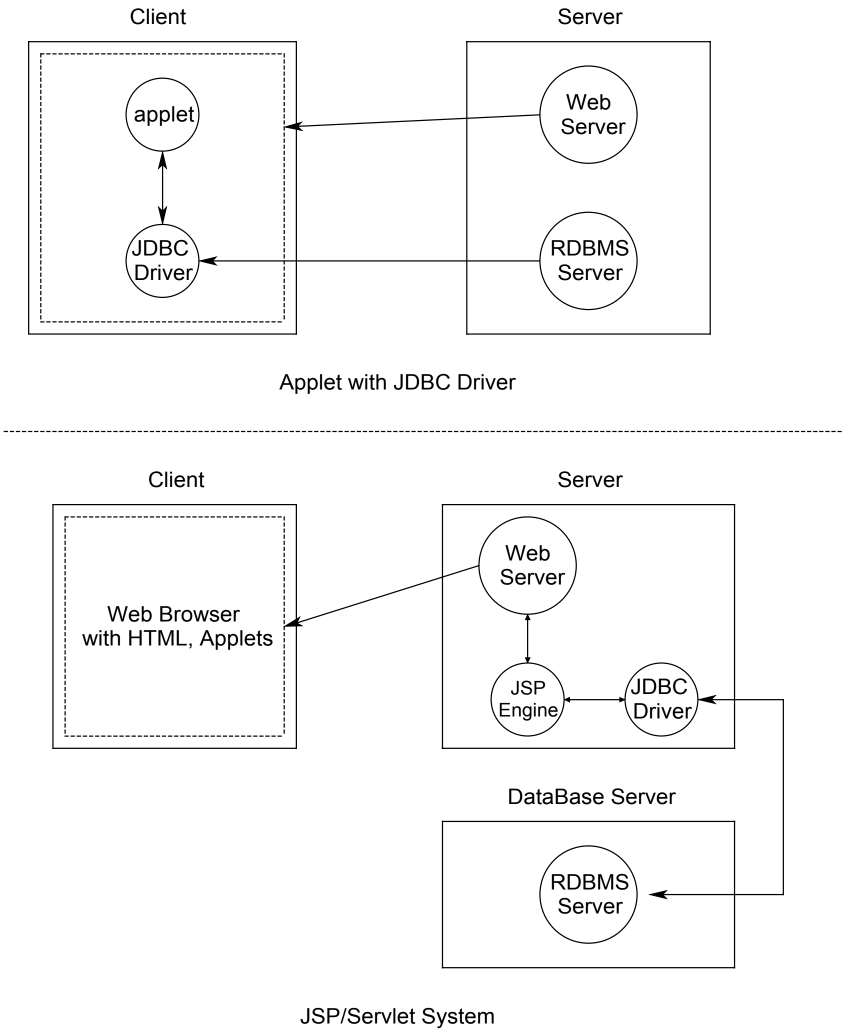

Figure 2-6 JDBC deployment scenario: applet with JDBC and JSP/Servlet.

On the other hand, embedding the database driver and application logic in the applet can give rise to major problems under several conditions:

- download time of the applet and JDBC driver can be substantial if the client is accessing the server over the Internet via a slow link or a heavily loaded network;
- all client browsers must support Java, otherwise they will have no access to the database;

- o clients using the application will create their own JDBC server connection that lasts an entire session (i.e. with 500 users using the applets simultaneously, 500 connections need to be established); and
- o this solution cannot work through a firewall unless the JDBC driver to the relational DBMS protocol is explicitly routable through that firewall.

Compared to the applet with a JDBC driver as mentioned above, the JSP/Servlet method (lower portion of Figure 2-6) has the following features:

- o there is no applet or JDBC driver to download to the client;
- o the browser using the Web application is not required to support Java at all;
- o the JSP has full control over how many JDBC connections are made to the server (i.e. the client never makes a direct JDBC connection to the server);
- o this solution can work readily through a firewall, only standard HTTP is used between the Web server and the client; and
- o this solution lends itself to an easily secured implementation, simply by adding secure socket layer support to the Web server.

From the above, it is certain that both JDBC deployment scenarios can provide the EEIS with a thin client front-end to its databases. The 'applet with JDBC' deployment may be used for more complex data manipulation (e.g. visualising analysis results, interactive user interface etc). The JSP/Servlet deployment may be more suitable for managing millions of users (e.g. home occupiers, energy end users etc) accessing multi-DBMSs and dealing with relatively simple operations (e.g. monitoring energy profiles, benchmarking energy performance etc).

2.3.2 Electronic Gateway System

An electronic gateway system connects a Wide Area Network (WAN) (e.g. ATN, SONET, WDM, IP Switching) to a Local Area Network (LAN). The role of the gateway is to allow external service providers to access and control local devices (e.g. home appliances). The forms of gateway systems are various. For example, the PC can be a gateway for a home network. Refrigerators, Web-pads, telephones or specialised gateway devices can also take on this role. No matter what hardware is used, it must provide the function of connecting a local (or home) network to the Internet.

Although the application of an electronic gateway system has a large potential, there are still few manufacturers producing the system since the market has not matured yet. A representative commercial product of the electronic gateway system was introduced by Ericsson: the so-called 'e-service system' (Ericsson 2002). The e-service system forms a link between the broadband network, the Mobile Internet and the home network, enabling new services to be developed and distributed. Figure 2-7 illustrates the e-service system implemented in two places, locally in every e-service gateway, and centrally in the e-service centre. The e-service gateway, or e-box, is located between the home network and the broadband access network. The access network can be of any type as long as it supports the e-service system requirements regarding IP connectivity. The access network has to be always on while the need for bandwidth depends on the application. The e-service centre is the administrative centre of all operation and maintenance activities. The e-service gateways are supported and managed by the e-service centre. The e-service centre is also a place where distributed applications may be implemented. The e-service platform operates on the 'e-box service gateway', which is a combination of a thin server and a communication gateway. An e-box is a small computer system consuming low energy and permanently connected to the Internet. It creates the bridge between the broadband network and the home/local network, and between different networking technologies within the home.

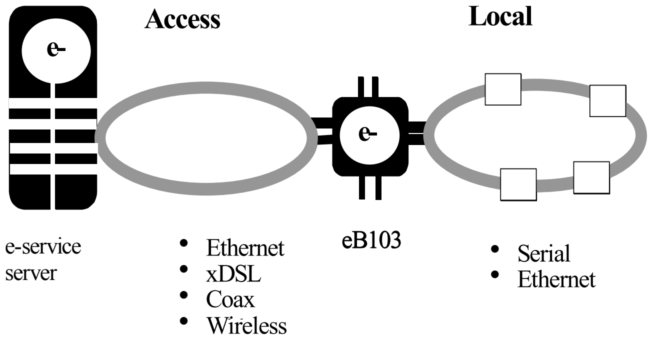

Figure 2-7 View of the network interfaces in the e-service system (Ericsson, 2002).

Figure 2-8 shows the appearance of the e-box, the hardware specification of which is as follows.

- CPU: 100MHz 486;
- 32 MB DRAM;
- no hard drive – 24 MB Flash memory;
- no fan;
- access network: ethernet 10 Mbit TP;
- local data net: ethernet 10 Mbit TP;
- RS232 serial port for use with a wire-based or wireless control network; and
- 5V supply to power any serial device;

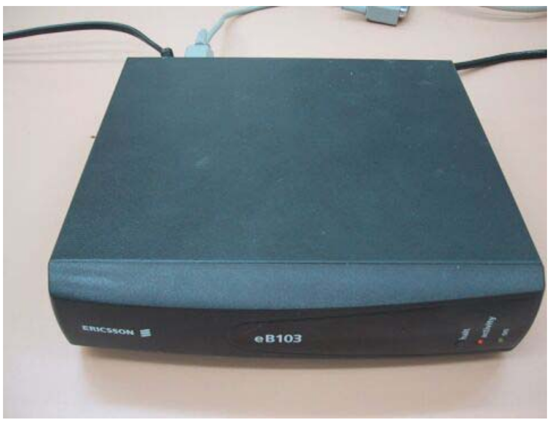

Figure 2-8 Appearance of the e-box.

The e-service centre is the software headquarters of the e-box system, which administers software bundles that are remotely deployable to each e-box and manage the system security. The typical placement of the e-service centre is in conjunction with the Access Network Provider (ANP) access servers, or on the e-service operator's IP backbone. Several components (i.e. e-server, certificate authority, service assurance, e-manager server, DMZ network and firewalls) may share one physical server, and some components may be distributed across more than one server.

The software application environment of the e-service system includes an Open Services Gateway initiative (OSGi 2002) service platform, and runs on a Linux operating system. The OSGi Platform is complementary to most other internal network communication standards or initiatives currently underway. The OSGi Service Platform is focused on the application layer and is open to almost any protocol, transport or device layers. The OSGi Service Platform is designed to bridge various communication standards in a consistent fashion. The OSGi service platform is based on Java and is an open technology that can run on multiple platforms including services gateways, consumer electronics equipment, household appliances, communications appliances, computers and more. It allows developers and service providers to build applications that are platform and vendor independent offering greater choice and flexibility.

The e-service centre and the e-box communicate over a virtual Intranet (or VPN) that can overlay any IP network infrastructure if certain conditions are fulfilled. The e-service system enables the secure and transparent communication between them. The service application software embedded in the gateway compliant with the specification of the OSGi can also be installed/updated remotely by service providers located elsewhere on the Internet. For example, the device drivers can be remotely downloaded to the e-box to manage the process of local data monitoring and appliance control. Due to the software capability of the e-box, the control algorithms are implemented either in the e-box as an embedded program or at a remote system over the Internet.

Using the OSGi-enabled interface such as the e-service system gives rise to two main advantages: secured data communication and remotely deployable software management. Since the electronic system was designed for secure communication, it is expected that the system will ensure appropriate confidentiality in managing the data as a private intellectual property. On the other hand, unlike existing home automation systems or building energy management systems, monitoring and control algorithms may be implemented by deploying software applications remotely. This feature provides the on-line energy service with flexibility for the future because newly developed energy saving control algorithms can be deployed immediately without changing on-site configuration. Lindfors et al (1998) pointed out the necessity of this remote deployable software system from their experience in the field energy monitoring study with the early prototype of the e-box system.

Considering the advantage of the Internet converging media, the system will be competitive when a number of building service information for energy management but also for other services (e.g. building security and health care) are integrated. Once this integrated system has been established in properties (i.e. homes, offices, industrial premises etc), not only can security systems, heating systems and lights be operated remotely, but they could also be made to respond automatically to energy market prices. In the home care sector, for example, the service could provide peace of mind to relatives of the elderly or disabled people through security and monitoring services (e.g. indoor temperature, CO alarms, motion detectors etc). These are but some of the target domains of the EEIS.

The most significant merit of the OSGi-enabled interface for the EEIS is placed on the openness and flexibility in connecting heterogeneous systems (devices or communication protocols). The comprehensive system connectivity will allow the EEIS to establish an integrated and interactive communication between millions of users, energy managers and utilities in a simple and economical way. Various types of monitoring/control devices can be handled despite differences in their communication protocol. A massive monitoring/control network could be established on the basis of the Internet.

Consequently, the applicability of the advanced information technology is considerable for the new approaches toward demand/supply energy management. In the case of utilities using this service, for example, they could remotely control electricity supply and demand. In the case of demand side management, this might be implemented via contracts with customers allowing control access in return for a reduced cost tariff. This means that utilities can take control of appliances in individual homes or offices that have a contract. Then, the utility can manage the desired peak load by adjusting the electricity demand within a reasonable range. For instance, the set-point temperature of air conditioners within a contracted customer's premises can be adjusted down to avoid extreme peak loads.

2.4 Multiple User Interfaces

The confidentiality of energy information is often a significant issue. While some information should be available to the public in the context of an energy strategy, other information must remain exclusive to a certain group of users. For example, while weather data may be generally available, domestic energy consumption must remain confidential. Even if new legislation makes it possible to share information, different levels of access will likely be required. To support the collaborative activities of widely distributed users, it is necessary to provide the means to manage information resources and control access to them.

The availability of current information technology, including Web-based network programming, Java applets and network security, leads to the possibility of such multiple user interfaces. As described by Figure 2-9, user interfaces can be implemented on the basis of three different types: client-based (stand-alone applications), server-hosts (Web-client) and hybrid client-server (secured Web-client).

A client-based user interface is a stand-alone software application. It is installed in a local host and is operated by a limited user group. Since the interface itself contains the database connectivity and the integration agent, the system integration can be implemented in a host or a local network without the added complexity of network security. Because it is a software package, a relatively large capacity for modelling and analysis can be accommodated. This allows end-users to handle sophisticated data processing tasks. While such users can take advantage of the full facilities provided, they will require advanced knowledge to maintain the system.

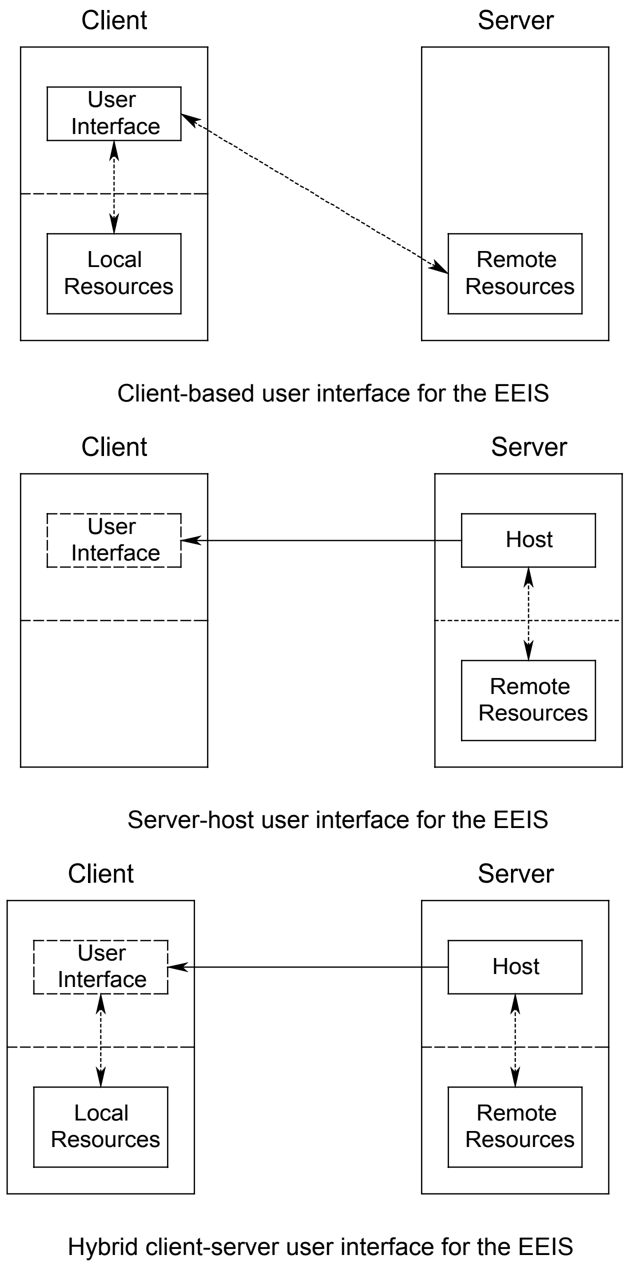

Figure 2-9 Types of graphic user interfaces for the EEIS

In a server-host system, the user interface is downloaded from the server-side whenever users request it. This is generally implemented with Web-server and client (e.g. Web browser, Java applet etc). Users can not only get information but can also make transactions with the server-side applications. Because all resources, including the interfaces, databases and applications, are managed on the server-side, the client-side has no burden of maintenance.

The server-side requires high performance hardware and software systems to deal with the potentially high number of simultaneous user connections. The server system also requires additional management for system security. There are, however, limitations in manipulating the data resources for analysis, modelling and other sophisticated tasks because the performance of the interface is affected by the network bandwidth. For instance, if the interface of a Java applet contains complex functions, so that the file becomes large, the time needed for downloading may be prohibitive. The interface procedure should be designed as economically as possible unless the network bandwidth is broad enough to achieve an acceptable response time. In addition, the interface cannot handle local (client-side) resources such as databases, files and so on without additional security devices.

The hybrid client/server user interface is an extension of the server-host user interface. While the interface is downloaded from the server-side, it can handle both the local resources and the server-host resources. In order to implement this system, an additional security system is required incorporating user authorisation, certification and signed applets. By being a thin client and a secured system, users can make transactions easier and safer.

A specific user interface will be determined according to the following considerations:

- Who are the users - home owners, energy managers, an exclusive group or the public?
- What kind of information do they require - energy profiles, simple indicators or sophisticated analysis?

- o How many users are expected – a few or millions?

While the type of user interface suited to the EEIS depends on where the user interface exists and how it operates in the client-server network system, an efficient data transaction mechanism is required to bridge the gap between the EEIS and the different types of users. The multiple user interface system should handle various user requirements via different types of user interfaces in a consistent way because ultimately the database accessed by the user interfaces is the same. The requirements associated with user types and the user supporting system will be discussed in Chapter 3 and Chapter 4 respectively. The implementation of the multiple user interface systems were made on the basis of Java technology described in Chapter 6. the Client-based user interface in Figure 2-9 and the server host user interface (the hybrid client - server user interface) correspond to the stand-alone EnTrak system (Section 6.2) and Web-based application system (Section 6.3) respectively.

2.5 System Architecture

The SQL compliant database system for the EEIS increases the potential for large-scale data management and connectivity to existing DBMSs. The network based software technologies, such as Java, offers suitable tools to support the sharing of information and ideas among a scattered audience, and can be readily equipped with an information security system.

Current interface technologies may be adopted to make a front-end to the databases of the EEIS and to integrate different applications (e.g. energy modelling programs, data analysis software packages etc) into the EEIS. The middleware of database interfaces, such as JDBC, will allow the EEIS to manage distributed information resources, which contribute to large-scale energy/environment partnerships. Moreover, future energy service providers, who may wish to exploit advanced communication technology such as electronic gateway devices, may require an interface to construct two-way digital communication networks. The combination of OSGi-enabled service gateway and energy management could help consumers reduce their energy consumption and increase comfort.

On the basis of current information technologies, the architecture of the EEIS has been conceived as illustrated in Figure 2-10. The communication and connectivity between the components is established through system interfaces and operated via the Internet-based client-server arrangement. Data within database management systems possessed by other organisations may be collected using database connection protocols such as JDBC. The data transmission between the EEIS and data sources, such as monitoring devices embedded within buildings, may be enabled through electronic communication systems.

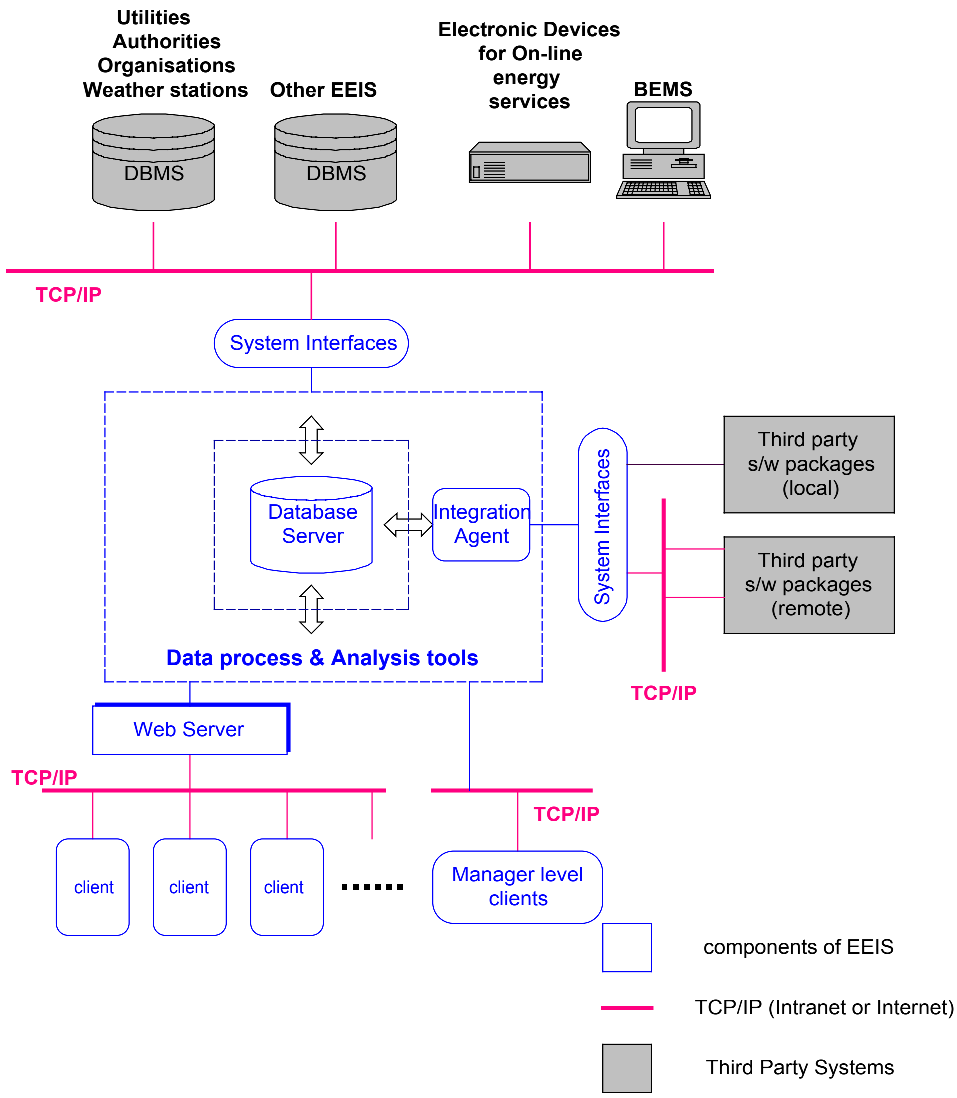

Figure 2-10 System architecture of a prospective EEIS system.

Third party applications, such as modelling packages, may be combined with the EEIS via an integration agent that co-ordinates data communication and combines third party applications, databases and user interfaces. User interfaces, at the front-end of server-side components (such as databases and modelling software), are implemented within either Web-clients (i.e. applets and dynamic HTML) or an application package.

The system architecture of the EEIS aims to increase the flexibility of the system so that it can deal with various sources of information and different applications. To integrate the distributed resources seamlessly, the system interfaces are required to couple system components and to make connections with external information sources. On the basis of the review of the communication interface technologies, the connectivity and data flows in the EEIS are illustrated in Figure 2-11.

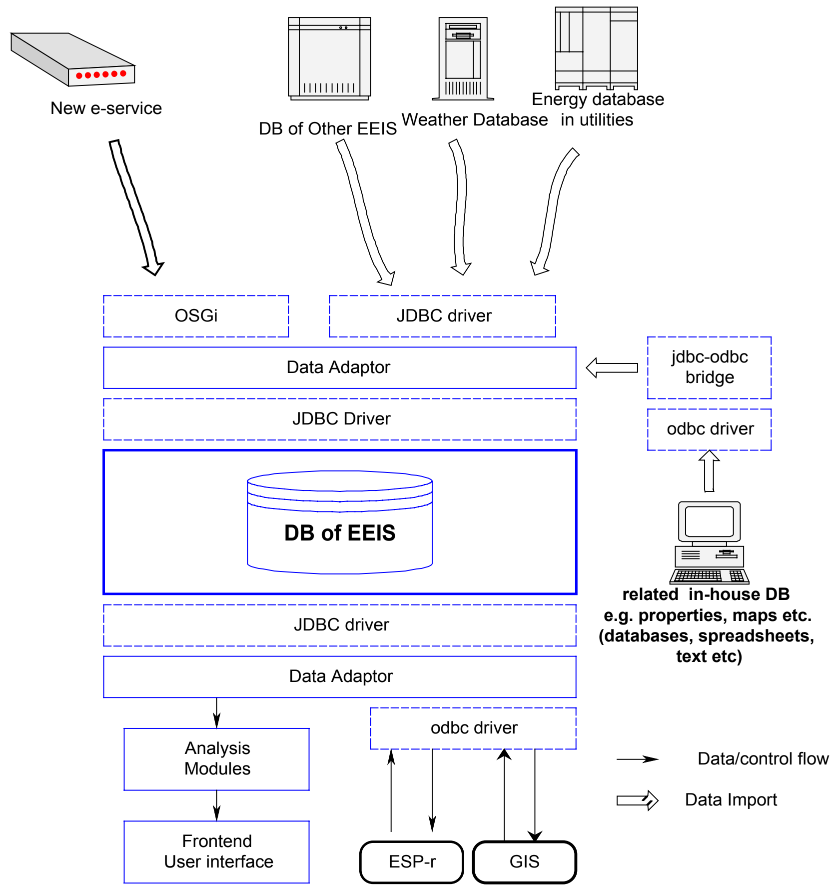

Figure 2-11 The system interfaces and data flow in the EEIS.

Whatever platform the database management systems runs on, the database-to-database connectivity can be established through JDBC and DBMS drivers as long as they are SQL-based DBMSs. In the case of normal office data media such as spreadsheet format files, database files or text files, the data can be imported to the database using a JDBC-ODBC bridge as long as they are SQL compatible. In general, because the data format is compatible between the SQL based databases, the data transmission can be made easily. A data adaptor module will be required to control the data flow and any necessary adjustments (i.e. aggregating data, selecting corresponding items, converting scientific units etc) from the external data sources to the database. A data adaptor could consist of data translation procedures and JDBC.

In the EEIS, relevant data such as energy consumption, climate and so on may be collected either automatically or manually. If on-line metering networks are available within an organisation, the metered data may be collected through a device-to-computer interface from distributed sensors. In an organisation not equipped with such electronic metering, workers in the organisation will need to input the data manually from paper media such as invoices and publications provided by the utilities and the Meteorological Office.

Metered data is usually stored in a database in a certain format so that they can be managed systematically for query and further analysis. Users can obtain simple information such as energy profiles based on the data held within the database. In addition, once the energy data are maintained by a database management system, it becomes easier to import or export the data from one database to another.

Meanwhile, it is important to prevent unauthorised access to the system to limit the potential for an attack from elsewhere on the Internet. All the normal considerations, such as authentication and user access control, must be considered. The privacy of the data being transmitted over the Internet must also be taken into account. Fortunately, secure techniques such as the SSL (Secure Sockets Layer) protocol (Freier et al 1996), SHTTP (Secure Hyper Text Transfer Protocol) (Rescorla et al 1998), firewalls and so on are available, which can be shared by the Web-based network management system. Since the issue of Internet security is associated with computer networks on which the EEIS would be based, organisation awareness and actions are required as discussed by Hawkins et al (2000).

2.6 Summary

In terms of the number of users and the growing bandwidth, the Internet infrastructure is expanding, and destined to become a ubiquitous communications medium. It is expected eventually to replace traditional communication methods such as telephone calls, analogue broadcasts and EDI with Web-based alternatives. The new software technologies are driving traditional businesses to adopt on-line business-to-business integration. Java technology offers tools to construct applications for a network-based EEIS, providing a simple way to access information held in distributed corporate databases, and allowing the EEIS to inter-operate with legacy applications such as energy modelling software packages.

The SQL compliant database system for the EEIS is designed to handle large data-sets with connectivity to existing DBMSs. In addition, the middleware database agents based on JDBC allow the EEIS to use distributed database management systems; this significantly contributes to the large scale energy environment partnership. Further, new communication technology (e.g. OSGi) allows the EEIS to provide new energy services such as remote meter reading, intelligent aggregate control and real-time energy/environment performance monitoring.

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Chapter 3 EEIS System Requirements

The review of current Information Technology in the previous chapter identified the technical possibilities that may be employed within the envisaged EEIS. A framework architecture for the EEIS has been proposed on the basis of these available technologies. This chapter is concerned with the contents of the EEIS. The following sections discuss core issues such as the nature of the information to be manipulated, the analysis capabilities needed and the system integration requirements. Through this discussion, the specific functional requirements of the EEIS are defined.

3.1 Nature of Information

The information dealt with in the EEIS is associated with energy action planning to reduce energy demand, increase the energy efficiency and alleviate environmental impact (i.e. low CO_2 emissions) in pursuit of sustainable development. Therefore, the term of sustainability assumed in this thesis is mainly focused on the energy demand/supply management among a number of measures for sustainability. Figure 3-1 summarises the information required within a decision-making process for energy action planning. The term of 'entity' is here a demand/supply system corresponding to the subject of energy/environment management. The information on an entity includes property type, ownership, energy systems data, constructional characteristics and geographic location. The energy information associated with the entity may contain consumption/supply data, fuel type and cost. The environment information is related to weather factors affecting the energy demand/supply of the entity, indoor climate and the gaseous emissions caused by energy consumption. Other relevant information could be extensive, including land-use, population, finance and operation.

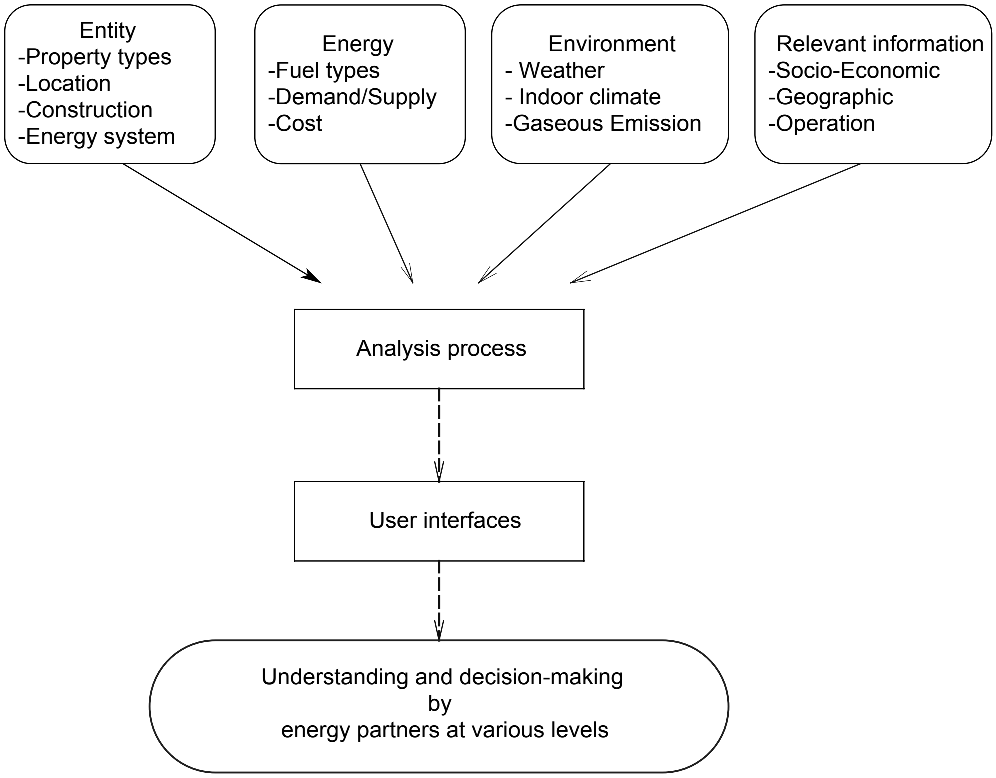


Figure 3-1 The process of decision-making.

On the other hand, the possible scale of such information is extensive. An entity could be a building (or an energy system), an institution, an urban area or an entire region/country. Time-dependent information such as energy consumption, weather and indoor climate may be collected for different time intervals (quarterly, monthly, daily, hourly or less). In addition, the sources of the information are dispersed. For example, the information required for energy management decision-making may be available internally (e.g. within an accounts department) or offered by an external sources (e.g. a utility company).

Further, the nature of the information needs depend on the decision-making level. Figure 3-2 illustrates the nature of the data and its analysis at levels within the EEIS.

Characteristics of Information	Tactical	Strategic
Source	Largely internal	External
Scope	Specific Narrow	Varied Broad
Level of Aggregation	Detailed	Aggregate
Time horizon	Historical/present	Future
Occurrence	Immediate	Old
Needed Accuracy	Great	Minimal
Frequency of Use	Very frequent	Infrequent

	Examples	
Frequency	Hourly Daily	Monthly yearly
Report	Routine	Investigative
Entity (Building)	Individual	Regional national
Analysis	Quantitative	Qualitative

Figure 3-2 Model of information requirements by level of decision-making (based on a model by Gorry and Scott-Morton 1971).

In general, strategic analysis is likely to be at the large scale (organisation level or local government level), have a long-term base, and be qualitative. Tactical analysis is likely to be at the small scale (single building level or mid-size organisation level), have a short-term base (hourly or daily) and be quantitative. For example, a realistic regional energy strategy could be built from an estimation of renewable energy sources, an evaluation of the energy demand profile, and consideration of the match between the two. Local authorities, as planners and energy managers, need extensive information that includes not only energy-related factors but also socio-economic factors such as land use, population density, industrial statistics etc.

In a regional energy management context, many analyses are made possible with frequently recorded data (Munro 1996):

- regional matching of CHP/renewable energy projects;
- real-time identification of abnormal energy demand;
- assessment of the potential for improved control;
- improved post-implementation monitoring;
- measurement of low load, low efficiency boiler running;
- cost allocation in shared buildings; and
- advanced tariff analysis.

In a building, the use of hourly and daily energy data are different from that of monthly data (Haberl et al 1990). Monthly energy data is used to investigate the overall performance of an energy system (e.g. the efficiency of a boiler or the assessment of equipment capacity). On the other hand, hourly energy use data can be used to evaluate the performance of system operation and control.

In terms of consumer energy motivation, more frequent and immediate information helps consumers change their behaviour. While the ability to make comparisons with earlier consumption enables consumers to identify changes in their energy consumption pattern, a benchmark test by which consumers can compare their energy consumption pattern with other similar types of buildings will provide an even stronger energy saving incentive. Wilhite and Ling (1995) observed:

"We have tested 'past-use' comparative feedback, but there are other forms for comparative information which might stimulate awareness. One of these is the provision of the average energy consumption for a typical household with characteristics similar to the billed household. There are greater practical difficulties and costs associated with this 'like-household' comparison, but our study has demonstrated that the potential returns are so large as to merit examination. Another specific kind of information which would make energy use more transparent would be to disaggregate each household's energy consumption by end-use, i.e. provide a breakdown on how much energy goes to space heat, water heating, appliances, lighting etc. This would require an audit of each customer's home and a regular update of information, a costly exercise in light of present technology, but the imminent implementation of two-way metering communication will soon make this feasible. The potential returns of this kind of super-feedback merit study."

In other words, by allowing citizens to compare their energy consumption with that of their neighbours, it may be expected that local action to reduce consumption may follow. While energy information is essentially used in professional decision-making, it can play an even greater role when used to motivate end-consumers.

3.2 User Types

The nature of information use is variable, depending on the decision-making level. The range of users of the EEIS is therefore broad, ranging from home occupiers to policy makers. The types of users can be broadly classified according to the level of their involvement in the hierarchical structure of the information process. Figure 3-3 describes the types of users that are generally involved in the process of energy management. At the bottom of the hierarchy, practitioners may collect raw energy data regularly or irregularly. They may not be involved in analysis work, but concerned with routine work such as issuing formatted energy reports and visiting building sites identified as poor performers. The data collected from the field is generally stored in a database and managed by information administrators who support upper level decision-makers such as energy managers. The activities of these users are likely to be operational in terms of the level of decision-making.

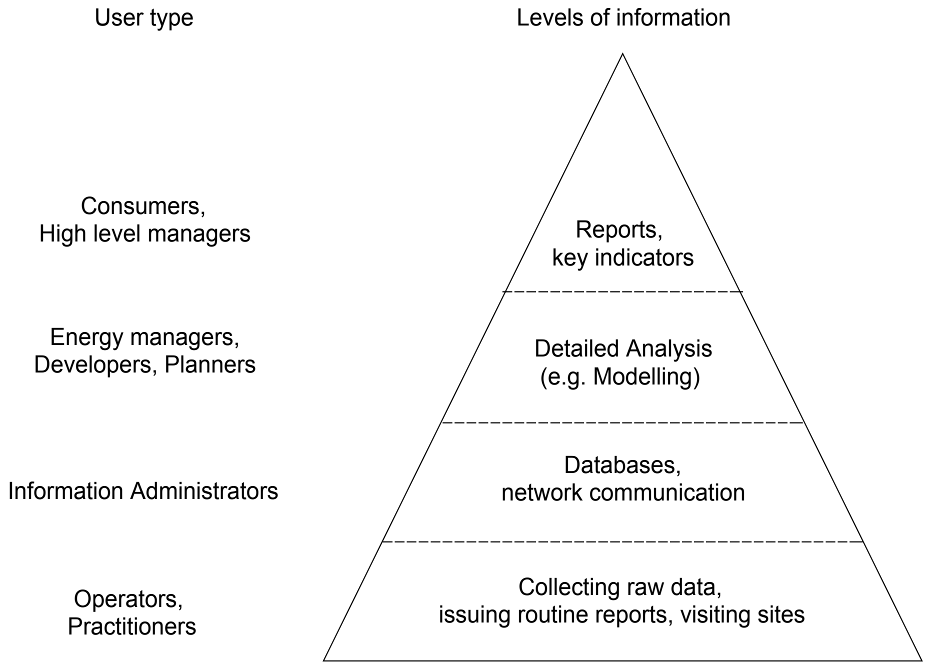


Figure 3-3 The hierarchy of decision-makers and information in energy management.

At the middle level of the hierarchical structure, users such as energy managers, planners, and developers require a wide range of information. Bamborough (1993) presented practical energy management tasks, which energy managers of multi-premise organisations have to carry out. The activities described in Table 3-1 imply decision-making at all levels (i.e. strategic, tactical and operational).

Decision-makers at this level need to be equipped with well-organised database management system and analysis tools. However, such systems generally require high level skills and a high cost infrastructure. Building designers, energy managers and local authorities are unlikely to be so equipped. Even where the technologies for decision support have been improved, and various software programs are available, decision-makers will still have difficulties in utilising such tools in their routine work. Munro (1996), who made a survey of the requirements of energy information system throughout Scottish local authorities, found that these authorities experienced serious

Table 3-1 Practical issues tackled by energy managers in multi-premise organisations (Bamborough 1993).

Practical Energy Management Tasks
1.Carry out energy analyses on site D08035006 including microclimatic analysis for both rigid and natural wind shelter schemes.
2. Generate status report and issue to clients.
3. Run an update of fuel purchasing policy and cost analysis.
4. Assess environmental impact of current fuel and energy mix and provide analysis in view of new EC directive.
5. Prepare a 10 minute audio-visual presentation on energy savings achieved in current year and proposals for the future.
6. Prepare a briefing meeting with client on 'next generation' building design.
7. Run an analysis on building performance within own ownership and on all sites, nationally, using both national and own templates.
8. Provide an analysis of projects showing over-consumption together with recommended solutions (full costing not required at this stage).
9. Generate schedule of site visits and inspections.
10. Update records from estates and maintenance.
11.Generate and transmit information updates to local, national and international data banks.
12. Compare and report on microclimate analysis over the last six months.
13. Compare overall building energy performance, i.e. cost, energy use and pollution analysis by client, function, fuel and system type.
14 Check metering integrity and run billing reconciliation.

problems extracting the data they require, despite the widespread use of IT systems. This was found to be due to:

- a lack of functionality within existing systems, particularly with respect to auto-checking and flexible report generation;
- poor data exchange between current systems; and
- a lack of user training and awareness.

In addition, some sophisticated analysis techniques are not simple enough for the users at this level to carry out. At this level, decision-makers are not able to carry the burden of maintaining the hardware and software system and orchestrating their application. Instead, they normally require access to a few simple performance metrics matched to their job function. That these metrics are extracted from distributed data sources and subjected to complex analysis, is of no interest to such users.

Ultimately, at the top level, decision-makers such as home occupiers, high-level managers and policy makers may want tailored reports or key indicators that they can obtain on demand. While not being involved in any analysis process, they still require an interface that can deliver processed information in a simple way. Without knowing it, end consumers such as home occupiers are using monitored data to assist their decision-making for reducing energy use. Going further, householders and building owners could initiate appraisals of options for refurbishment to improve the performance of their property. While such appraisals may employ sophisticated modelling techniques, again these users would be unaware of this action. However, the automatic use of simulation-based modelling is not simple. Some relevant reference information (e.g. weather data, construction properties etc) would need to be acquired without any help from the system users. It is envisaged that the EEIS would support the automatic retrieval of such data at the time of service enactment.

As the characteristics of the information required for decisions at each level are diverse, and the sources of it are both external and internal, dealing with such information is non-trivial. To address this, a data model must be designed to accommodate multi-scale and multi-variant data and to manipulate these data in a coherent and flexible way. Meantime, the Web-based user interface of the EEIS must handle multiple users, and possess certain essential features as follows.

- Easy access to energy information on demand. Web browsers are a cheap user interface and exist for almost every platform (MicroSoft Windows, Unix etc). Any user connected to the Internet can have access to the database and information resources.
- Central data resources shared by different user groups (home owners, estate departments, consulting companies, building owners etc). Central administration makes resource maintenance easier. The service centre manages user accounts and supports users by providing different interface designs according to the user type.
- Analysis facilities on-line exploiting aggregated data in real time. The stored data in the EEIS database is analysed and via the Internet presented both on an individual and aggregated basis. The aggregated figures supply different energy agencies with important statistics. Using these facilities, a dynamic performance index can be generated from the database on demand.
- Additional reference information. HTML pages can have hyperlinks directly to energy advice Web sites or energy-related materials such as new regulations, energy tips etc. The referenced Web sites can be grouped to make the EEIS Web site a useful decision-support tool.

To foster energy awareness and motivation additional user interface functionality is required:

- Encouraging customers' energy saving motivation by providing elaborated energy use information. (e.g. frequent energy use reports and possibly real time monitoring and advice); and
- Providing active and smart control measures (e.g. remote appliance control, embedded smart control algorithms etc).

3.3 Analysis Capabilities

The analysis capability of the EEIS can be classified into comparative, exploratory, scenario-based and forecast analysis. Comparative analysis identifies problems with an entity's energy performance through:

- comparison with past performance (i.e. historical profile);
- comparison with entities in a scope (i.e. ranking and classification) or of different types;
- comparison with the performance of similar entities (i.e. benchmarking); and
- comparison with target performance criteria.

The purpose of exploratory analysis is to find patterns and characteristics within the energy and environment data. Understanding data distributions, identifying patterns and analysing temporal evolution all need qualitative answers for strategic purposes. Exploratory analysis entails an investigation of the nature of data by

- searching for trends;
- comparing the variation of one data channel with another (i.e. correlation); and
- discovering combinations of variables across several data-sets.

A scenario-based analysis evaluates the design options for an energy system. Detailed simulation programs can be used to evaluate alternative energy efficiency or supply measures. Further, GIS-based energy modelling can deal with dispersed energy resources such as renewable energy systems over a large area. Forecast analysis predicts the possible energy consumption over a future period so that a target plan can be established. For forecast analysis, statistical modelling (regression) or simulation programs may be exploited.

In implementing analysis techniques within the EEIS, one of the most significant considerations is to match the various information types and formats to user needs. The following sub-sections consider the application of conventional analysis techniques in a multi-scale data context and the options for displaying each type of information entity. Section 3.4 then discusses a new approach to analysis that overcomes the deficiencies of conventional analysis techniques when handling large volumes of data.

3.3.1 Conventional Analysis Techniques

Most conventional analysis techniques for energy/environment management including Monitoring and Targetting (DETR 1998) are associated with the following questions.

- How much fuel did we use?
- How much did it cost?
- What is the fuel mix?
- How have the costs risen?
- How has usage risen?
- How does 'this period' compare with 'that period'?
- What savings have been made?
- What are the unit costs?
- Who used what?
- Which users are the largest consumers?
- Which user has the biggest rate of increase?
- What is the optimum energy/fuel or contract/tariff option?"

In order to respond to such questions, presentation as well as content (i.e. data) is important in a decision-support system. As Unwin (1999) has pointed out, the requirements of interactive graphics software for the analysis of large data sets for interactive and experiential interfaces are that they

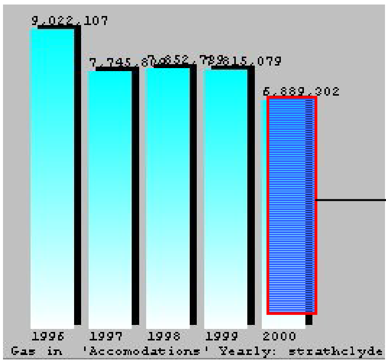
- o display a whole view (e.g. zooming in/out of the part of a geographical area or a time period);
- o re-scale result displays to accommodate different analysis periods; and
- o access data-sets corresponding to different scales (e.g. ‘drill down’ to focus on successively smaller scales).

Within the EEIS, multiple approaches to handling collective data and presenting outcomes are required as follows.

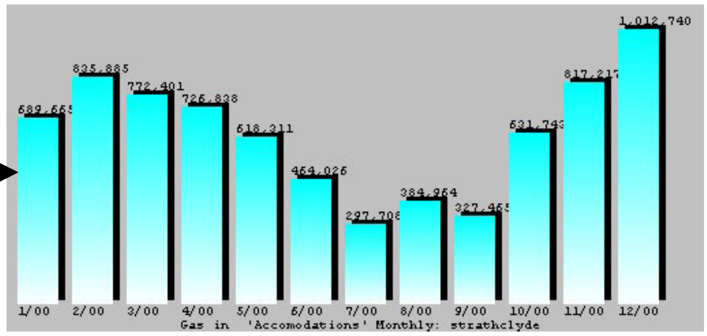
Profile

‘Profiling’ is a technique to identify the pattern of dynamic data over a period. Time-dependent data such as energy consumption and weather are usually presented in a bar or line plot chart. To handle the multi-scale data of the EEIS, analysis tools (e.g. profile viewers) must have facilities to re-size and re-scale the displays associated with the scoped entities.

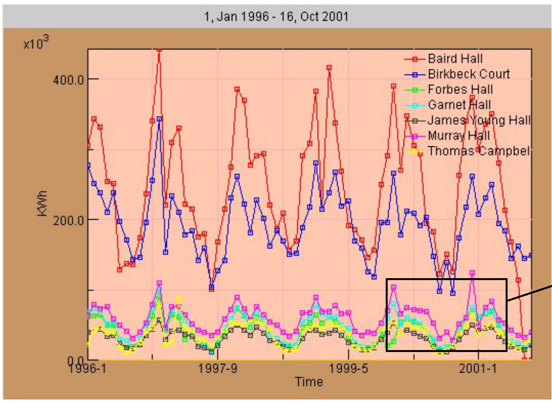
For example, a user-interactive profile viewer as shown in Figure 3-4 can instantly display re-scaled outcomes by simply zooming in on a period of the profiled graph. In a viewer, users can scan energy patterns over different time-scales from yearly to daily and less. The energy patterns must also be viewable at different resolutions from the large scale to individual entities. This multi-view interface requires a coherent data preparation mechanism as well as an interactive user interface.



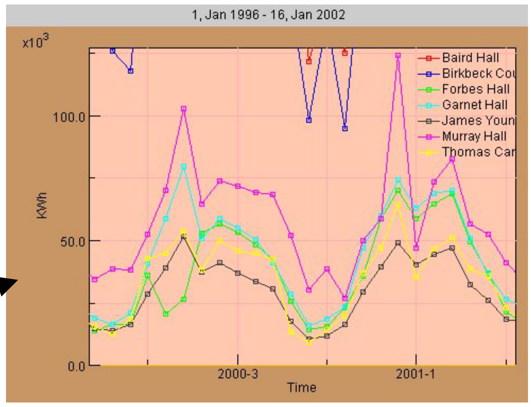
a) Overall yearly profile



b) Overall monthly profile



c) Individual monthly profile



d) Zoomed-in individual

Figure 3-4 A user-interactive profile viewer displaying energy consumption trends over different time-periods.

Ranking and Benchmark

The simplest ranking analysis is to sort a group of entities corresponding to a certain scope in order to identify the entity's relative performance. 'Benchmarking' is an analysis to evaluate a building's energy performance when compared with similar buildings in a region or an agreed performance criteria. Typically normalised indicators are used (e.g. kWh/m^{2}y). Manipulating a variety of entities in terms of their scale and type allows the rapid construction of helpful groupings.

Regression and CUSUM

‘Regression’ is applied to derive simple mathematical relationships between a parameter of interest and key drivers (e.g. energy use and degree-days). The technique is used to ‘understand’ how the drivers influence the key parameter. The regression graph of energy and degree-days, for example, has the following three principal features.

- The intercept, i.e. the point where the line cuts the energy axis at zero degree-days, shows the minimum energy consumption that is not related to weather.
- The gradient of the line implies how much the weather affects the energy consumption.
- The scatter (degree of dispersion of the data points in the graph) can be quantified by a correlation coefficient and gives an indication of the extent to which the energy use in a building is governed by weather.

This analysis method can be coupled with a comparison analysis for a group of entities. After making the regression equation (e.g. Consumption = A x Degree-Days + B, where A and B are constants) for each entity, users can identify which entities corresponds to poor control, which have the worst energy performance, and which are least responsive to weather variations.

CUSUM

The Cumulative Sum (CUSUM) of differences from actual or predicted performance is a graphical technique that allows savings accumulated from investment to be quantified and displayed (British Standard 1980). The role of CUSUM within the EEIS is to identify the impact of changes in the pattern of energy use, and identify the time of the last change. The quality of this analysis method depends on the validity of data and the relevance of the base line calculation, i.e. regression. The data should be prepared carefully. This technique is suitable for application at the small scale. At the large scale, it is difficult to obtain data representing an energy characteristic associated with a number of buildings because aggregating data is likely to lead users to incorrect results (see Section 3.4).

Energy Performance Classification

An energy performance classification is a method by which the entities in a scope are sorted according to their energy performance. It operates by placing entities in consumption bands. The technique allows energy managers to focus on poor performers within a certain group. Also, in terms of energy strategy, it allows policy makers to identify the structural pattern of energy consumption with respect to different sub-categories, classified by year of construction, type of properties, geographical region, heated area and so on.

Gas Emission

As gas emissions are related to property energy consumption, it is usual to utilise a conversion factor table from energy consumption to equivalent pollution units. The emission factors depend on fuel type, fuel grade, industrial sector, combustion technology and location. In addition, emissions associated with electricity use are calculated according to the fuel mix used for power generation in a particular geographical area.

3.3.2 Integration of Analysis System for Sustainability

The analysis in support of energy management involves various approaches, from identifying energy use trends to deriving information via modelling. The EEIS must therefore possess analytical capabilities at different levels since it may be applied to a single building or a group of buildings at the institutional, regional or national level. A single building can be an object of tactical analysis as part of a regional energy strategy. Through strategic analysis, some buildings could be targeted for improvement. These buildings would then be investigated by applying analysis techniques.

Thus, the analysis capabilities may be applied strategically to establish broad policy, and tactically to investigate particular design and operational changes. They allow users to make use of scenario-based planning, energy appraisals, environmental impact assessments, renewable opportunity identification etc. Strategic decision-makers identify problematic phenomena by looking at the patterns before they focus on a group of data to find possible causes or to quantify the phenomena for tactical purposes using dedicated statistical analysis techniques. Integrated energy reports must also be supported by the EEIS. For example, an Integrated Performance View (IPV) of a scope of buildings is shown in Figure 3-5 (Cairn 2000), which was created on the basis of the contents of energy management reports at a higher educational institute. An IPV report contains:

- general information on the scope (e.g. image logo of the scope, name, location, period, number of buildings);
- total energy consumption and cost;
- energy breakdown by fuels (e.g. electricity and gas);
- temporal profiles of monthly energy consumption with degree-days data;
- consumption trend over previous years;
- classification of buildings by total energy consumption and normalised consumption; and
- classification of buildings by gaseous emission-based performance indicators such as Electricity Performance Indicator and Fossil Fuel Performance Indicator.

The purpose of an IPV is to give an insight into overall performance and allow ready identification of the inherent trade-offs. High-level managers will require such information to assess overall performance and respond to questions relating to

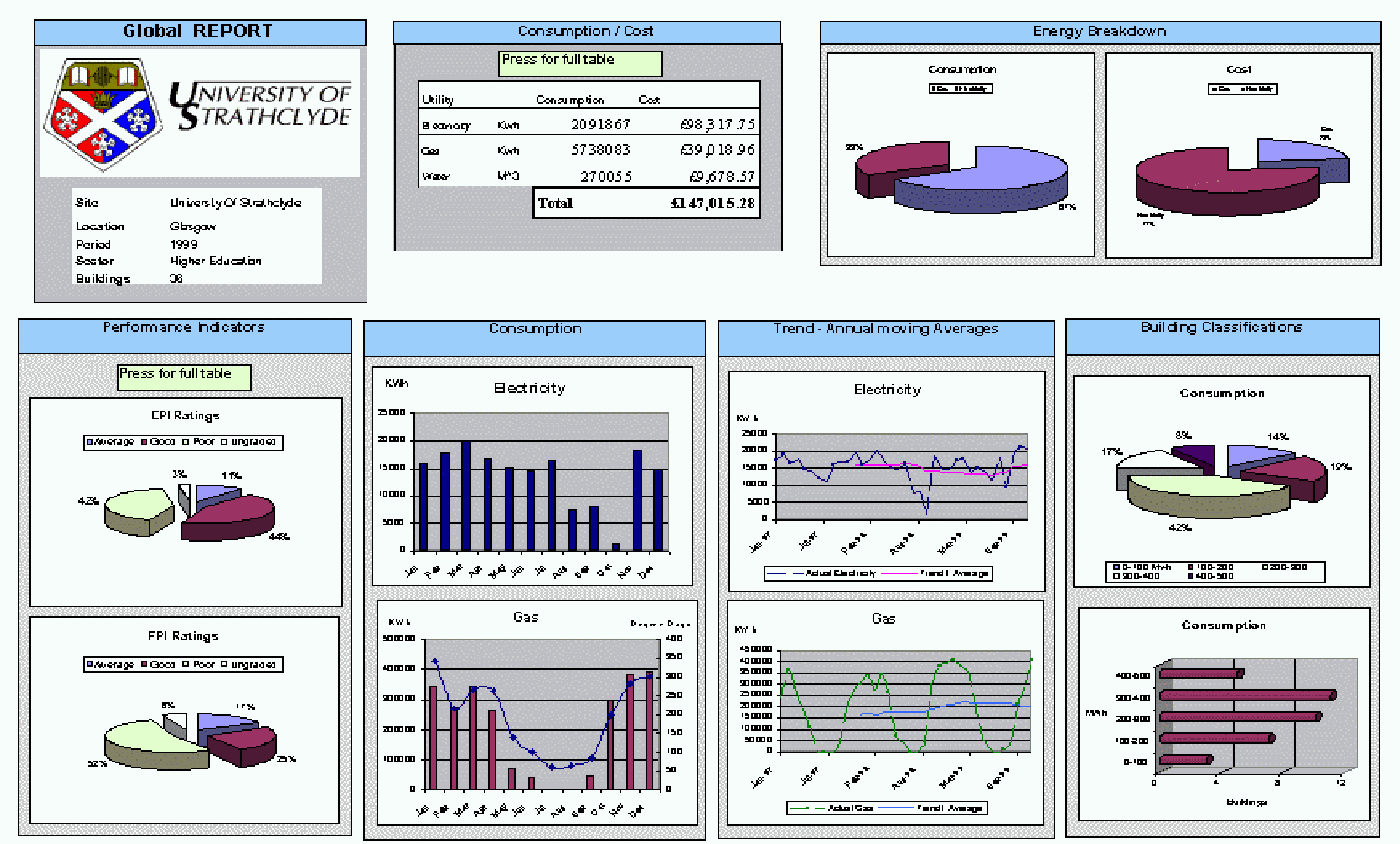


Figure 3-5 An IPV report of energy performance for overall buildings (Cairn 2000).

sustainability. The information is likely to have long-term based and aggregated data. The report is dedicated for setting energy policy for the next year. To fulfil the policy, high level decision-makers will consider both technical (e.g. system refurbishment) and non-technical measures (e.g. motivation, marketing etc). Taking technical approaches to improve energy efficiency, they would identify specific problems.

On the other hand an IPV may be more focused. as can be seen in Figure 3-6. Here the IPV may be more investigative in nature. It includes:

- general information on a specific building (e.g. a representative image, name, location, period of analysis, type (or function) of building, area and built year);
- energy breakdown of the building by fuels and performance indicator;
- benchmarks with performance indicators;
- energy use trend over past three years;
- monthly consumption profile of electricity and gas of the building; and
- regression and CUSUM analysis of the building.

Buildings with poor performance indicated in the global IPV may then be investigated within the specific IPV. The IPV may be issued regularly to personnel responsible for individual buildings in order to support autonomous energy management. The IPV reports are generated on the basis of recorded data. Although they inform decision-makers for the assessment of past performance, there is still a lack of information to enhance better energy and environment performance.

Seeking the measures to improve energy performance of current buildings, sophisticated analysis techniques such as simulation are often adopted. The IPV in Figure 3-7 presents a result of the evaluation of the potential of renewable system using energy simulation (Clarke et al 1999). This IPV contains:

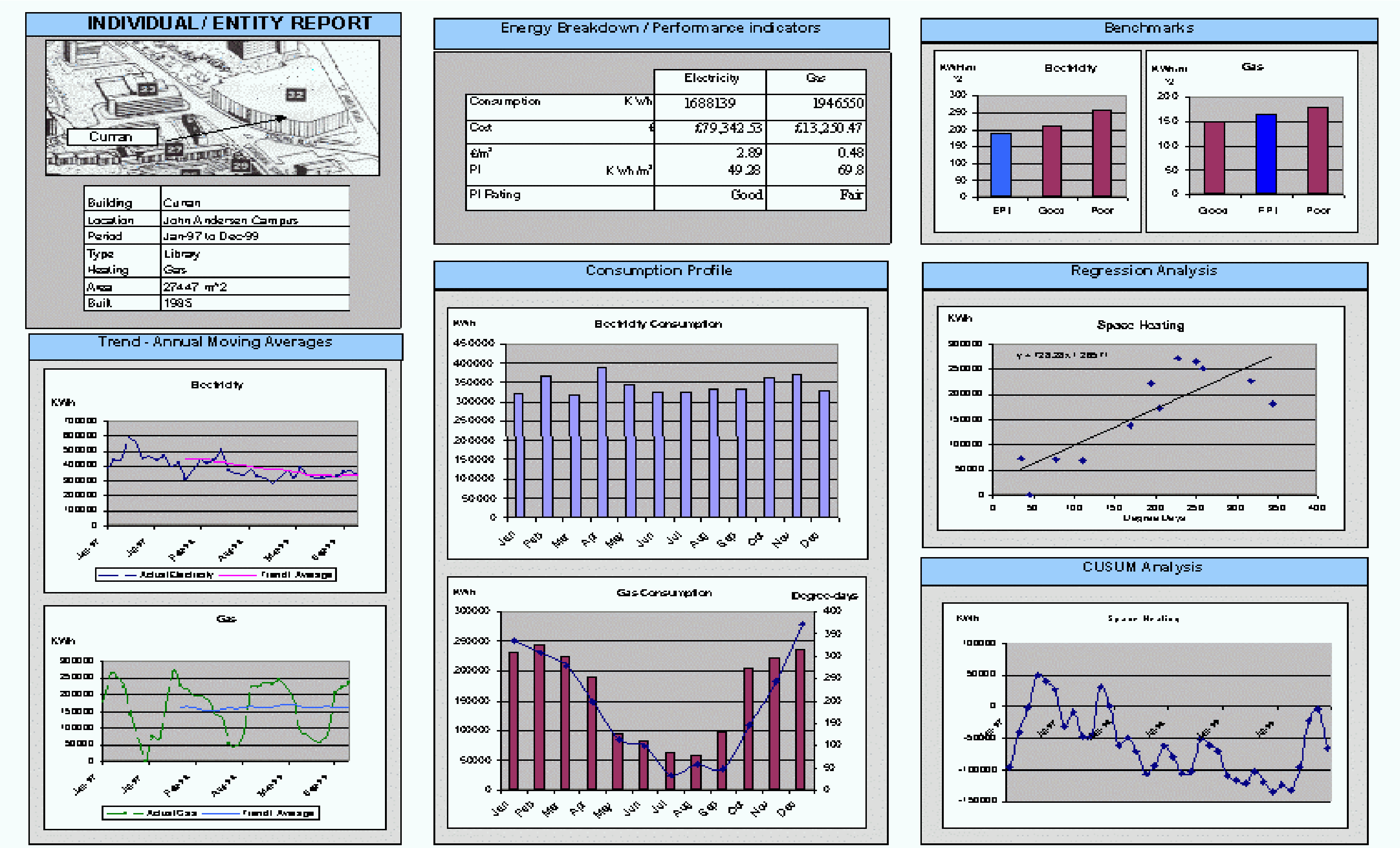


Figure 3-6 An IPV report of energy performance for a specific building (Cairn 2000).

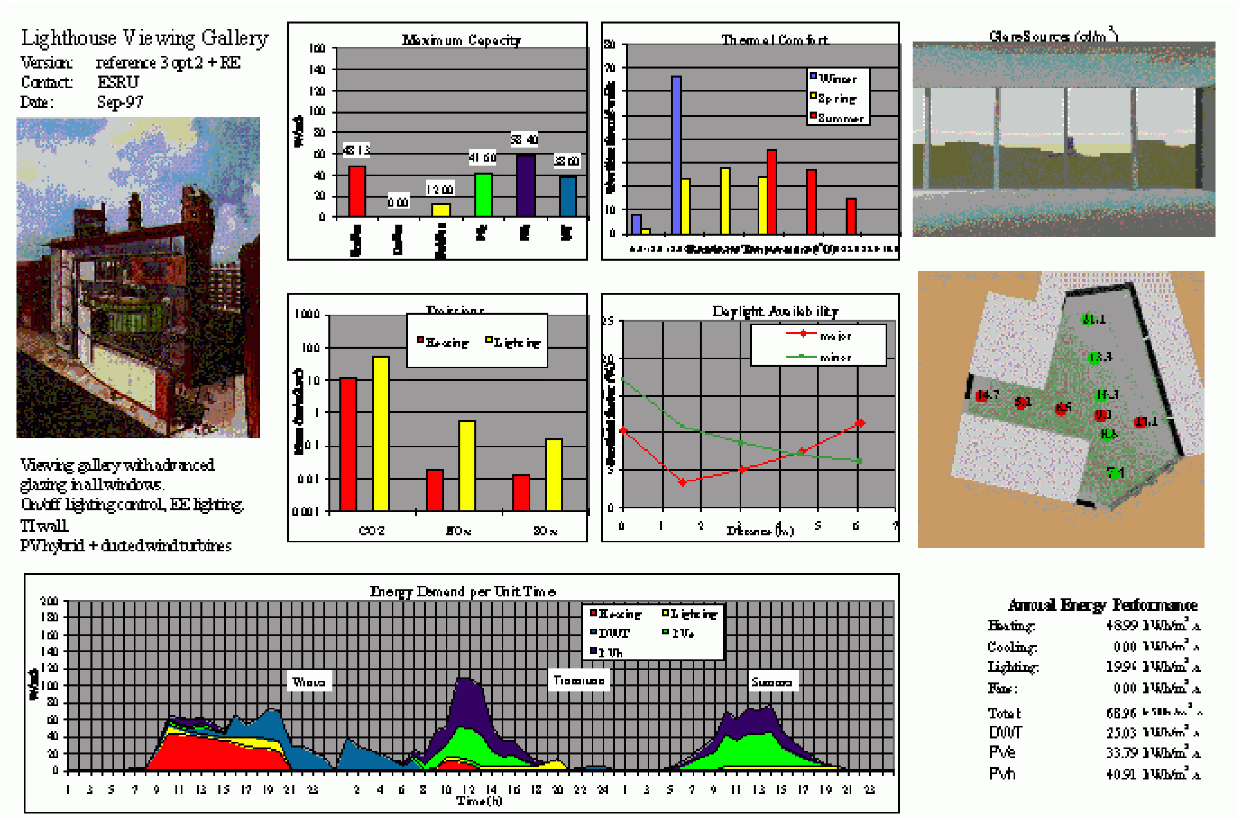


Figure 3-7 An IPV for the appraisal of embedded renewable energy system (Clarke et al 1999).

- general information – project descriptors, images and contact details;
- maximum capacity – diversified totals for heating, cooling and lighting to represent critical equipment sizes and hence capital costs;
- thermal comports – temporal distribution of some thermal comfort index to indicate the severity of any departure from an acceptable comfort zone;
- visual comfort – temporal distribution of some visual comfort index to relate visual discomfort to any excess/lack of light or problematic contrasts in the field of view;
- environmental emissions – seasonal primary energy demands converted to equipment gaseous emissions to define environmental impact;
- daylight availability – distribution of daylight levels to give an indication of the potential for daylight utilisation;
- glare sources – potential glare sources are highlighted and quantified within a synthetic colour picture;
- primary energy consumption – patterns of primary energy demand, by fuel type, expressed as cumulative profiles for typical seasons; and
- energy performance indicators – these comprise the building's annual energy consumption per unit of floor area for each of the fuel use categories.

This analysis is intended to achieve a high-level of demand-side energy reduction without compromising the building's thermal and visual comfort levels, in order to increase the effectiveness of deployed active renewable energy systems (e.g. photovoltaic components and ducted wind-turbines). The IPV therefore contains the simulation results of thermal comfort, visual comfort, gas emissions, plant capacity as well as energy demand. Even more detailed information (e.g. hourly temporal data at the zone level) is involved in this appraisal.

Similarly, in terms of regional scale energy/environment management, local authorities can make yearly energy pattern graphs based on total energy consumption, and they may find a couple of properties consuming more energy when compared to similar properties. Monthly energy profiles may then be examined and analysis methods such as regression employed to identify the cause of the problem. Clearly, the collection of high frequency energy data will allow poor performance to be quickly identified and corrected.

As reviewed above, while the data resolution of IPVs may vary from yearly to hourly, and from a scope of building groups to an individual room, both levels stem from the same analysis context. Simulated data as well as real data are employed to assess energy performance and set up an energy strategy. The predicted performance may then be verified by using monitored data. Whether data are real or virtual, energy and environment data associated with a building should be managed in a consistent way.

It is, therefore, necessary to develop an integrated system of tactical/strategic analysis properly equipped with user interfaces that can handle multi-scale data. The integration of strategic and tactical information processing within the EEIS system gives users access to substantial information resources based on formal energy/environment performance assessments.

The data extracted from the database must be transformed to produce an informational data model, which represents a consolidated, aggregated and time-dependent view of the data. For example, the energy consumption data may be selected according to duration and a scope. The data itself may not be suitable to make a monthly energy profile or a daily-average energy profile because such aggregated data are unlikely to be available from the database. The format of the data must be re-sorted according to the analysis required. The process of this transformation is likely to affect the performance of the whole analysis system dealing with multi-frequency and multi-scale energy data within the integrated analysis system. An efficient mechanism for the data preparation is required.

3.4 Exploratory Analysis

3.4.1 Difficulties in Handling Multi-scale Large Data Sets

When dealing with an enormous volume of data in the EEIS database it is impossible to convey qualitative information using conventional data display techniques. For example, Figure 3-8 shows a line graph displaying the energy profiles of 66 entities within higher education establishments. Since the magnitude of energy consumption varies considerably, and the number of entities is large, it is almost impossible to appreciate the inherent message. When the number of entities is hundreds or thousands, the situation degrades further.

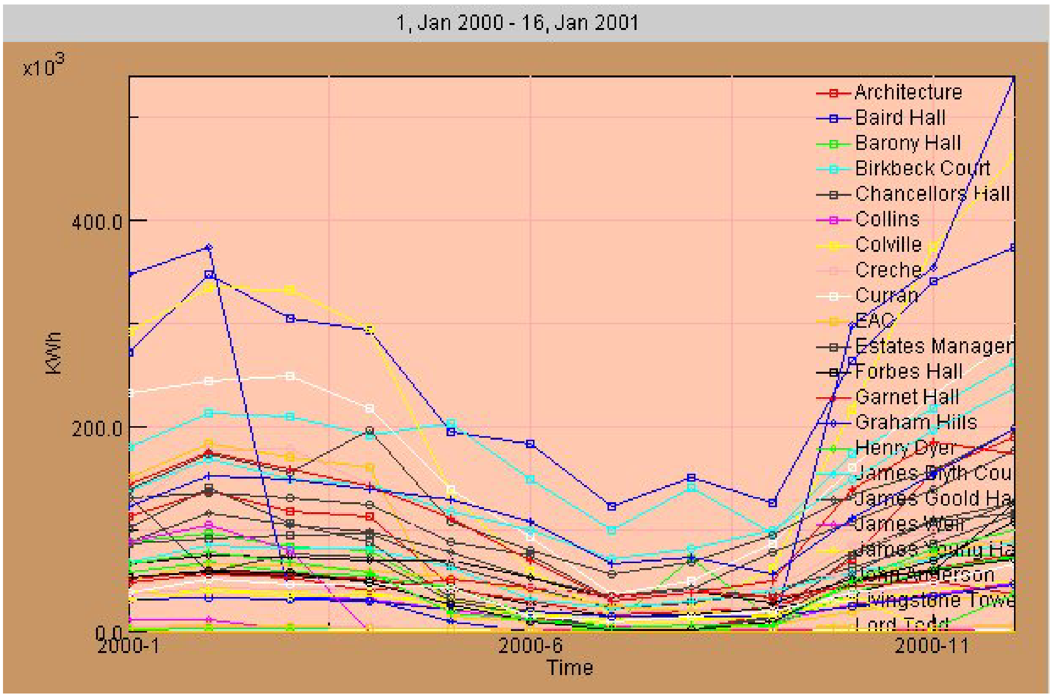
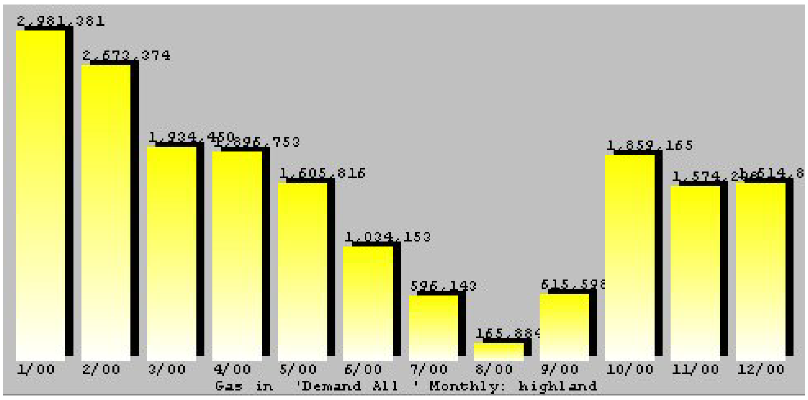


Figure 3-8 A line graph showing the monthly energy profiles of 66 entities in a higher educational institute.

When dealing with multi-frequency data, the data must be sorted at the same frequency. If statistical analysis is supported by data of a poor quality, the result of the analysis is likely to mislead decision-makers. An example of a misleading result is illustrated in Figure 3-9, with data taken from a local authority's energy database. Although the outcome looks reasonable, the data are mixed without considering the frequency or filtering faulty data. The reliability of the outcome becomes questionable. Though data quality is crucial, it inevitably contains faulty data when gathered from various input channels (e.g. energy bills, automatic metering systems etc). Hidden errors are difficult to detect once they have been stored in a database.



a) A monthly gas use profile of a scope.

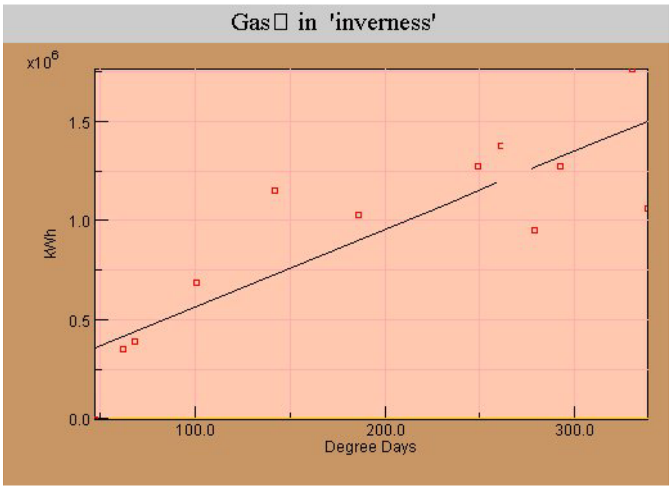
Gas in 'Demand All ' Monthly: highland

	2000-1	2000-2	2000-3	2000-4	2000-5
Dalneigh R...	41,704	41,084	37,034	29,620	-66,128
Dingwall A...	284,174	348,997	19,317	174,942	113,223
Dingwall Li...	17,407	13,494	8,547	11,227	3,052
Dingwall P...	47,530	55,322	44,683	73,640	11,964
Diriebught ...	56,326	19,693	36,624	29,426	21,309
Drakies Pri...	62,507	63,389	61,712	58,043	30,234
Drummond...	50,359	56,172	57,454	59,660	50,185
Drummond...	0	0	0	0	0
Farraline P...	67,275	35,989	39,451	44,074	26,483
Fire Brigad...	44,317	32,527	34,544	35,925	35,376
Haugh Court	10,734	5,095	911	2,170	1,585
Holm Prim...	58,947	40,953	62,264	52,708	28,326
Housing 2...	0	0	0	0	0
Housing F...	48,009	0	0	4,064	2,010
Inverness ...	211,408	226,741	186,731	141,507	111,953
Mackenzie ...	48,628	16,777	31,262	25,093	18,173
Merkinch P...	87,294	80,502	65,351	65,093	28,682
Millbank Pri...	24,265	262,564	1,917	17,235	12,482
Millburn Ac...	160,406	37,751	132,458	95,036	58,334
Millburn Ac...	0	0	0	0	0
Miller Acad...	3,020	2,988	-6,091	3,362	0
Muirtown P...	32,005	56,890	56,447	60,371	31,689
Nairn Acad...	269,012	146,029	223,430	159,837	123,945
Nairn Court...	0	2,692	0	0	0
Offices 33/...	0	134,162	0	0	11,285
Police Stati...	69,039	68,026	90,569	4,333	4,333
Pulteney H...	58,846	65,260	68,545	59,034	63,852
Spectrum L...	52,840	37,948	37,469	40,905	18,205
SWork Pre...	0	3,005	2,699	0	0
Thurso Hig...	4,015	277,223	5,618	-5,603	12,328

b) Data

Figure 3-9 A monthly energy profile graph and the data aggregated for the graph.

An example of this can be seen in Figure 3-10. Although the result of a regression analysis for a group of entities can be found, it is doubtful that the result can faithfully represent the energy performance of the entities because the individual characteristics of the entities offset each other by aggregating them. This analysis technique lacks measures to identify problematic entities and assess overall performance at a glance.



a) Results from aggregated entities.

Gas□ in 'inverness' : highland

Entity(EAZ)	Gradient	Intercept	R
Ach An Eas Home	107.552	18,605.15	0.84
Burnside Home	81.378	25,659.168	0.606
Cauldeen Primary School	716.863	-102,027.62	0.18
Charleston Academy	326.567	93,458.562	0.314
Corbett Centre	-13.903	20,529.015	0.004
Crown Primary School	203.036	483.885	0.799
Culloden Academy	-0.627	590.171	0.002
Dalneigh Primary School	223.248	11,299.799	0.093
Dalneigh Resource Centre	98.817	-6,267.839	0.129
Diriebught Roads Depot	165.312	-16,789.673	0.514
Drakies Primary School	166.003	11,486.697	0.89
Drummond Special School	66.213	35,456.582	0.476
Drummond Special School	0	0	□
Farraline Park Library	121.604	8,236.919	0.714
Fire Brigade Headquarters	49.73	20,249.791	0.518
Haugh Court	11.616	1,115.494	0.115
Holm Primary School	174.999	2,093.784	0.859
Housing 24 Anderson Street	-6.147	1,681.065	0.401
Housing Factor 14 Anders...	42.383	-3,601.892	0.105
Inverness High School Co...	401.352	383.815	0.222
Mackenzie Centre - Inverne...	99.241	938.913	0.639
Merkinch Primary School	231.516	-2,102.641	0.824
Millburn Academy	477.635	-27,950.148	0.733

b) Results from an individual entity

Figure 3-10 The results of a regression analysis and the data aggregated for the analysis.

Likewise, quantitative analyses such as regression or CUSUM are not suitable for the assessment of the energy performance of a large scope of entities. The chance of making an incorrect interpretation by aggregating energy data from dissimilar entities is low.

Conventional analysis techniques are only reliable when meeting the prerequisite that all data are correct. Even if data are available and reliable, the statistical approach to the evaluation of the energy performance of a group of buildings or a region has not proven successful. For example, the Normal Performance Index (NPI) is a controversial index because:

- o it cannot respond to a specific region’s circumstances even if there is a correction for degree-days and ;
- o the entity type must be defined clearly otherwise the benchmark test does not make a meaningful point (in practice, complex buildings with different usage cannot be clustered into a specific type).

Since there are inadequacies in delivering information to decision-makers using conventional analysis techniques, especially when handling multi-scale and large volume data, it may be better to show individual data than to misapply analysis techniques. New approaches are therefore required to allow decision-makers to:

- o identify problematic entities (e.g. over-consumption, unusual patterns) ;
- o detect faulty data easily;
- o perceive overall patterns without distortion; and
- o assess the overall energy performance of a group of entities.

3.4.2 Data Visualisation

Recent data analysis technologies have introduced a methodology of data visualisation, which displays an overall perception of data in a view and makes use of the eye's unparalleled ability to recognise inherent structures and relationships. The purpose of such a data visualisation system is to transform numerical data into pictures in which structures of interest become perceptually apparent (Poulet 2000). A GIS-based data visualisation is a valuable tool for conducting exploratory data analysis on spatial data. A GIS software tool coupled with the EEIS provides an environment within which to explore energy/environment characteristics geographically. In Figure 3-11, the distribution of energy use in an urban area can be displayed on a GIS map.

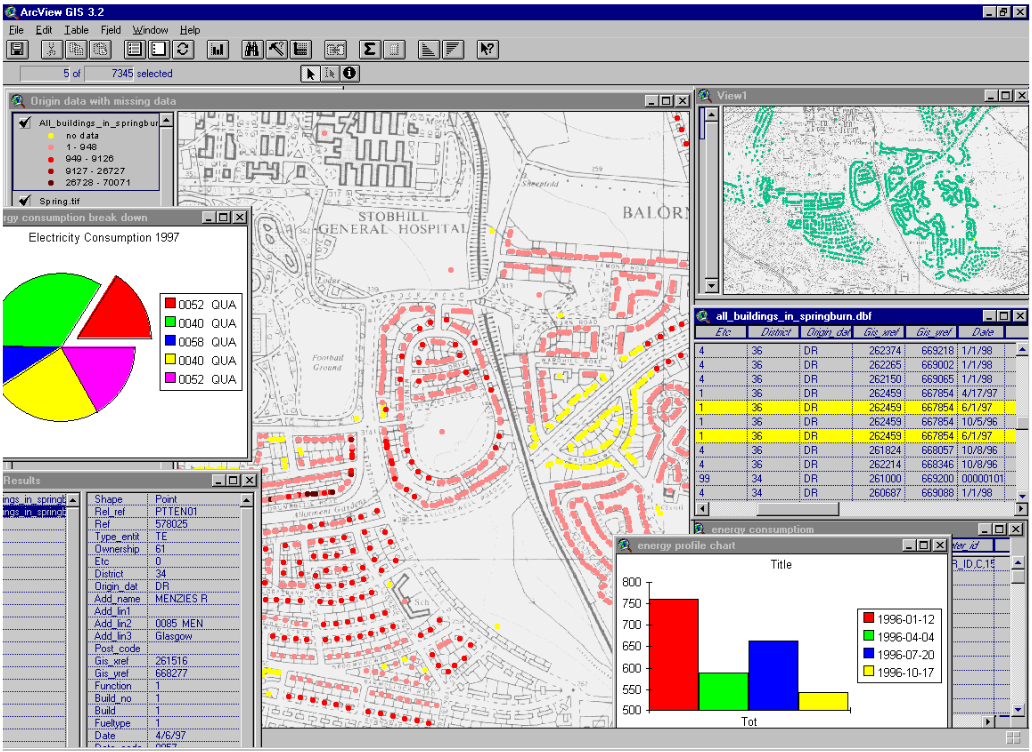


Figure 3-11 A GIS map view.

Such a map view provides decision-makers with an appreciation of problematic areas or the potential of renewable energy systems. While GIS-based visualisation is useful and broadly used for exploratory analysis, it is still limited to 2D and is weak at transforming numerical data into informative views, offering only a restricted set of visual attributes by which to convey information (e.g. position and colour).

3D data visualisation can provide a mechanism to present characteristics or patterns associated with parameters conveying socio-political, energy, environment and other relevant data. 3D visualisation enables the data analyst to rapidly analyse large quantities of data (potentially millions of entities), aiding understanding of data distributions and the detection of problematic patterns. There are a variety of 3D visualisation systems in use at present. These can be classified into three broad groups: mappings, presentations and dynamics.

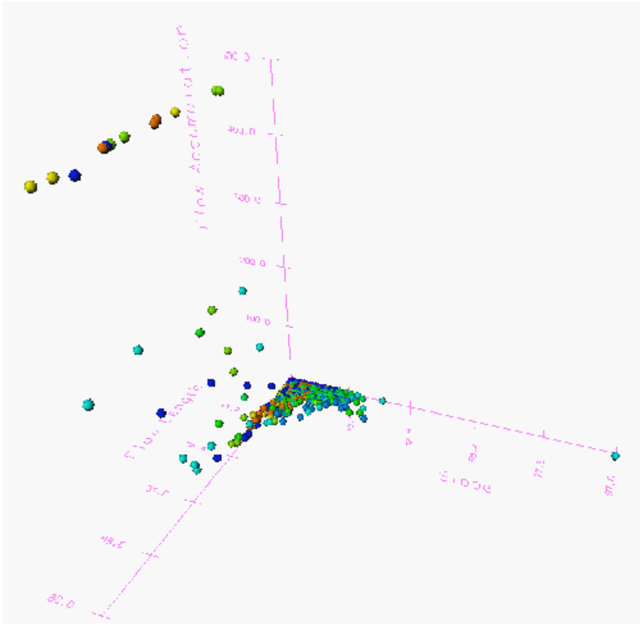
Mappings

Mappings from the data domain to the visualisation space use some aspect, property or value of the data items to produce a mapping to objects within the visualisation. Benedikt (1991) proposed the idea that attributes of an object could be mapped onto intrinsic and extrinsic spatial dimensions. Extrinsic dimensions define a point in space, given by a set of Cartesian co-ordinates. Intrinsic dimensions specify an object's attributes in terms of size, shape, colour, texture etc. Benedikt also outlined the rules for this cyberspace, which help to clarify the positioning of objects within cyberspace, with the objective of avoiding crowding.

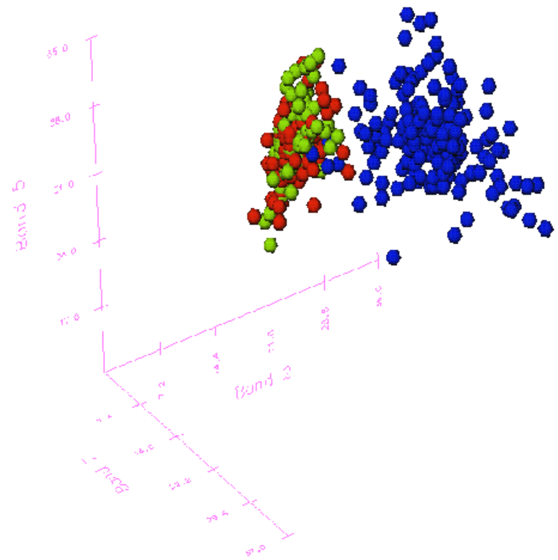
Figure 3-12 shows an example of the data space model using geographic data-sets (Gahegan 1998). To construct the data spaces, the only basic visual attributes of position (x, y, z) and colour (c) are used. Figure 3-12a represents a data space with a hydrological theme, showing flow length, flow accumulation and slope.

The user is able to study the problems of class separability within and between the data spaces. The colours are fixed throughout all the data spaces, giving the user a means of tracking data from one space to another.

Figure 3-12b shows a spectral data space to identify inseparability between different groups. The data space is formed by the automated assignment of data channels, searching for correlation among them. The inseparability between the red and yellow groups is clearly visible as is the differentiation of the blue group. This kind of information is helpful when designing a classification scheme.



a) Hydrological data space showing slope, flow length and accumulation



b) Spectral data space formed by cluster analysis and showing inseparability between green and red.

Figure 3-12 Example of mappings from the data domain to the visualisation space (Gahegan 1998).

Gahegan presented a four stage process for configuring data spaces:

- o “Assignment of channels to data spaces. This can be done by an expert, a knowledge base or in an automated fashion using techniques to maximise (minimise) correlation between data channels. Techniques used so far are: simulated annealing, cluster analysis and multi-dimensional scaling. The results obtained by one method are not necessarily consistent with another.

- o Selection of channels to visualise. Since visualisation is restricted to three channels per data space, channel reduction may be required. Automated techniques can again be used, for example principal component techniques will identify the three channels which together account for the most variance in the data. Alternatively, the user may decide.
- o Scaling of data. To ensure that the graph axes are similar in length, channels of data are individually scaled. Again, various techniques may be used, including histogram equalisation.
- o Rendering. The resulting data spaces are rendered for the user to explore."

Presentation

Presentation visualisations concentrate on the appearance, accessibility and usability of the data and aim to provide a user-friendly interface. Cone and cam trees are, for example, a 3D extension to the more familiar 2D hierarchic tree structures. Cone trees are identical to cam trees except that they grow horizontally instead of vertically. The aim of cone trees is to allow a greater amount of information to be displayed and explored in an intuitive manner.

Figure 3-13 shows an example of a cone tree visualisation for a Unix file store. Cone trees are constructed by placing the root (here the root directory) at the top of a translucent cone. All of the subsequent 'child' cones (i.e. sub-directories) are then equally distributed along the base of the cone. This process is repeated for each node in the hierarchy, with the base diameter of the cones reducing at each level as the hierarchy descends. This ensures sufficient space for all of the nodes present within the structure. Normally the tree can be rotated to bring a particular node into focus.

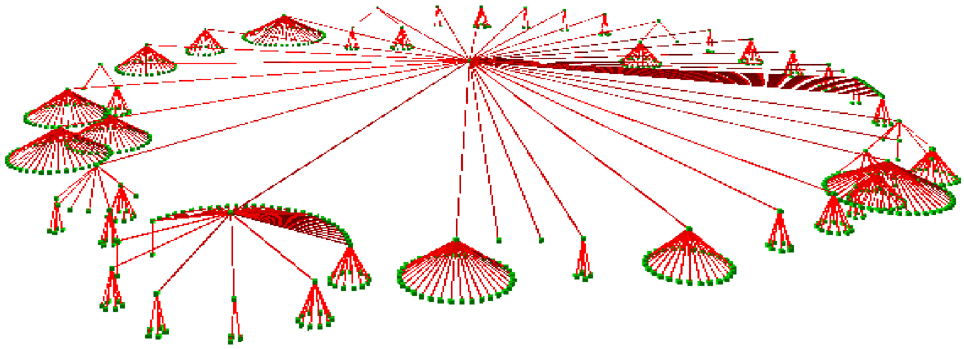


Figure 3-13 Part of a UNIX filestore as a cone-tree (Robertson 1991).

Dynamic

Dynamic techniques equip the visualisations with behaviour and dynamic properties, allowing the visualisations to respond automatically to changes in the data or to the actions of the user. Fish-eye visualisation is one of these techniques (Figure 3-14).

The fish-eye lens distorts the view so that objects close to the centre of the lens are greatly magnified; this magnification drops off rapidly the further from the centre that the objects are placed. This view results in objects that are at the centre of attention being shown in the greatest detail, whereas objects on the fringes are shown in lesser detail. This means that the user can study objects of interest, while still maintaining a view of the context and position of the focus in respect to the other objects. The use of fish-eye techniques could be beneficial where there are large numbers of objects within a confined space.

In many cases, for analysis that supports decision-making at the strategic level, the knowledge needed is of a qualitative nature. Understanding data distributions, identifying trends, analysing temporal evolution, all need qualitative answers for strategic purposes. 3D visualisation provides a simple and economic method to build qualitative knowledge. This approach will be useful for strategic analysis in the EEIS. The outcomes of the data visualisation will allow users to make a comprehensive interpretation. This is especially useful for setting up proper strategic measures and evaluating their effect where there are too many parameters (e.g. weather, social factors, equipment efficiency, control performance etc) to handle with statistical indicators (e.g. performance index, regression). 3D data visualisation also brings knowledge discovery to those who may not have such a deep grounding in sophisticated statistical analysis based on mathematical and logical algorithms. The explanatory analysis using 3D data visualisation may be beneficial before going for the detailed analysis involving conventional quantitative analysis techniques.

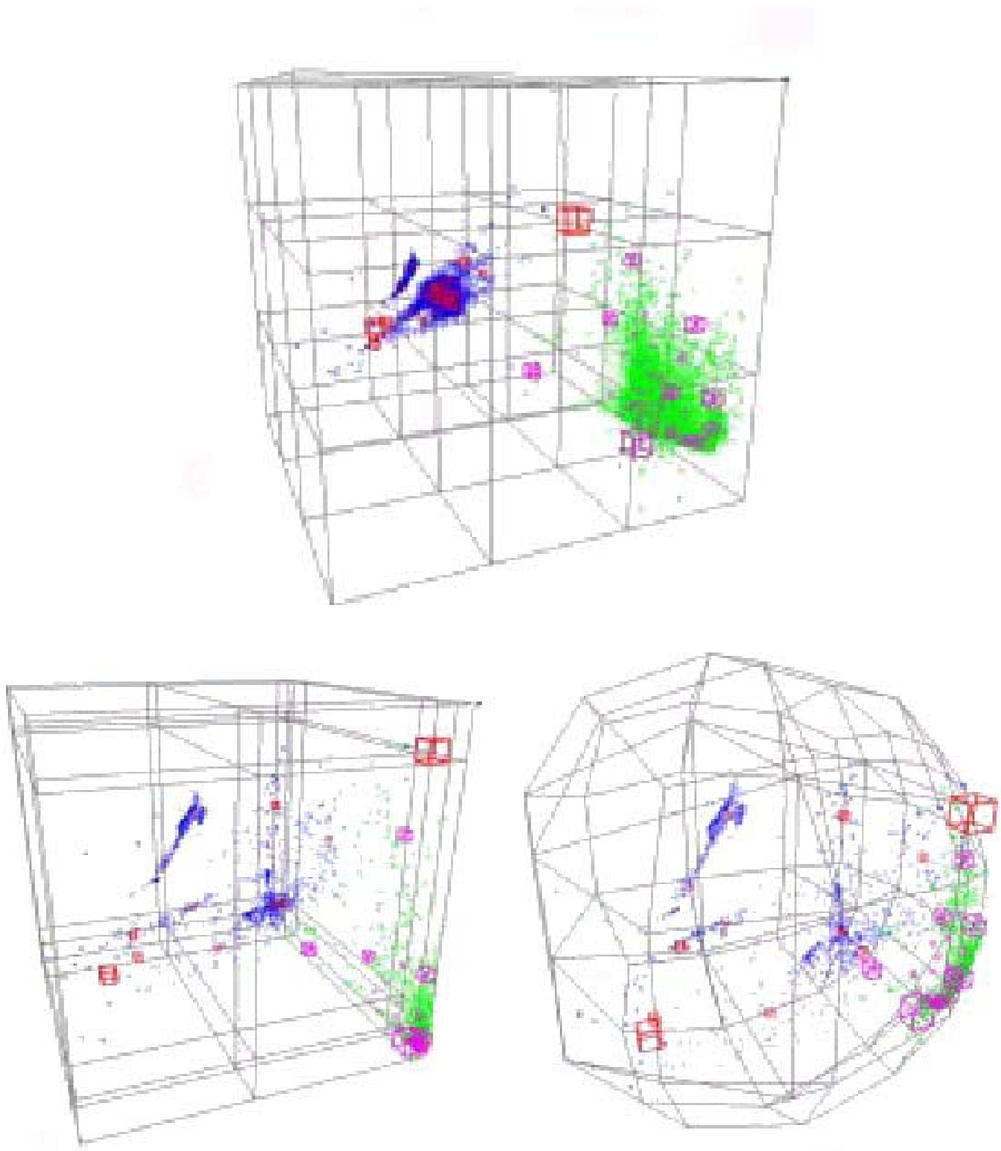


Figure 3-14 Normal, orthogonal and radial unconstrained views.

3.5 Interoperable System Integration Supporting Collaborative Decision-Making

In the context of large-scale data management, data is often missing because of human error during input, because information was unavailable at the time of input or because access to the data is not possible due to information privacy. One approach is to eliminate these entries that correspond to missing values. Although easily done, there is a high possibility of misleading users, especially when the data set is small. This approach may be suitable for a qualitative analysis using a large data set so that the result is unlikely to be affected by a small numbers of missing data items. When the missing data are crucial for a particular analysis, it cannot be ignored.

In order to compensate for these missing data, a virtual data item may be adopted. One solution to the problem of lack of information could be energy modelling. Modelling through the statistical analysis of historical metered data may be implemented at various levels from simple algorithms (average values, regression etc) to sophisticated ones (clustering, neural network etc). Based on linear regression techniques, for example, the characteristic mathematical model for single entities or entity clusters can be generated from the historically metered data. The effect of change may then be investigated by using the model. While this approach is relatively easy to fulfil, the resolution and validation of outcomes depends on the status of the existing metered data.

A predictive model can be used to predict the most likely value for a variable (e.g. energy consumption) on the basis of the values of the other variables (e.g. monitored energy consumption patterns for a similar building type). Such predictions are made by either statistical methods or detailed simulation programs. Statistical methods involve interpolation, regression and curve-fitting techniques. Detailed simulation programs such as ESP-r can be exploited to generate virtual dynamic data (Clarke et al 1997). These procedures can increase the resolution of available data – in terms of the spatial and temporal variations. By combining real and virtual meter data, with appropriate scaling factors, demand-to-supply matching at the large-scale is possible. Eventually, the modelling is used for energy planning, which involves energy prediction and scenario-based performance evaluation. It is important to provide decision-makers with easy ways to exploit modelling systems and to obtain useful information from them.

However, managing comprehensive tools for such modelling techniques still implies a heavy load as users. Users cannot be completely free from the burden of the system administration. Papamichael et al (1998) presented a building design advisor tool allowing use of sophisticated analysis tools from the early, schematic phase of building design without requiring users to have in-depth knowledge about these tools. The tool was also designed to allow comparison of design solutions with respect to multiple descriptive and performance parameters. It then acts as a data manager and process controller, automatically preparing input to simulation tools and integrating their output in ways that support multi-criterion decision-making. The tool is not so practical to be used as a real-time reporting facility for the interactive quality assurance due to the lack of effective communication facility between users and modelling experts. To tackle this, Donn (1999) proposed an Internet database of building performance information for quality assurance as well as a simulation veracity test and post-simulation analysis tools.

To realise the concurrent and interactive quality assurance, a supporting tool should be equipped with:

- a user-friendly interface allowing comparison analysis on multi-design options and multi-media graphic indices; and
- on-line data connectivity for reporting facilities allowing real-time communication crossing platforms and networks.

In order to address these issues, it is essential to integrate dispersed resource and provide users with two-way data and control communication. The integration agent in the EEIS is a supporting system for the collaborative energy partnership. It is implemented as software procedures, which have the following functionalities.

- Commissioning modelling to legacy software packages. The integration agent invokes third party programs according to a user's command. To manage the input parameters and the outputs, the integration agent needs to handle data connectivity between the EEIS and the modelling systems. In order to make the connectivity seamless, an intermediate process is generally required.
- Providing decision-makers with user friendly interfaces. Because users do not want to know, and do not need to know, the operational mechanism of the modelling system in detail, the user interface for the integration agent should be designed to hide the complexity of the modelling procedure. On the other hand, the outcomes should be presented to users in informative and efficient way using experiential multi-media tools.
- Making on-line data communication. The integration agent must handle network-based communication (i.e. intranet or Internet) for the data transaction between the EEIS and the modelling systems. The input parameters for executing third party modelling software programs and the outcomes should be transferred through a communication stream and shared in a network.

3.6 Summary

The functional requirements of the EEIS are to provide multi-level users with on-demand information and services handling a variety of energy information types (i.e. multi-frequency, multi-variate data). In terms of analysis capabilities, as well as the standard functionality of conventional monitoring and targeting systems, the EEIS provides integrated analysis support:

- the ability to manage large property sets as well as individual entities and to deal with a high diversity of entity types;

- the ability to classify properties by design parameters and/or fuel consumption; and
- the ability to predict or assess the energy performance of buildings under different conditions and to explore the savings potential of alternative design or control intervention.

The analysis capabilities may be applied strategically, to establish broad policy, and tactically, to investigate particular design and operational changes. They allow users to make use of scenario-based planning, energy appraisals, environmental impact assessments, renewable opportunity identification and so on.

Legacy applications including state-of-the-art building modelling packages can be integrated with the EEIS. These applications should be able to work together and with the data from the EEIS database under control of the EEIS integration agent that is responsible for adjusting the data formats and managing the communication between applications, database support and user interfaces. In order for the EEIS to implement a truly integrated decision-support tool, a variety of data types and software applications are made available simultaneously.

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Chapter 4 EEIS Prototype: Data Model and Analysis Model

As discussed, the nature of information and user types in the EEIS requires multi-scale and distributed data. To ensure the coherency of decision-makings at all levels, data should be accessed efficiently and provided in an appropriate format. In this Chapter, the data model, analysis process model and user support system are considered as required to deliver tailored information to decision-makers at all levels via the Internet. As a new approach to managing a large volume of energy/environment data, the feasibility of the 3D data visualisation technique is tested in support of identifying energy patterns and establishing effective strategy.

4.1 Data Model

The data model is aimed at increasing the efficiency of storage and retrieval considering the following requirements.

- The database must contain the information required for decision-support for energy planning at all levels. The decision-support system includes various analysis systems as described in the previous Chapter (i.e. energy profiling, classification, regression, gaseous emission mapping, GIS-based modelling, simulation modelling etc). The data model must accommodate the data shared by the analysis applications although it is not necessary to relate to the processing requirements of the analysis application.
- The supply and demand side should be dealt with for energy analysis (e.g. assessment of renewable energy systems, demand/supply matching etc). As a number of the modelling systems are involved in the EEIS, virtual data must be contained alongside real data.

- o Time-dependent data associated with energy demand/supply, climate, indoor environment and plant operation exists at various frequencies (minutely, hourly, monthly, yearly etc). While the resolution of the data required for analysis systems depends on the level of decision-making, the decision-making process sometimes requires drill-down tracking from a large volume of data to a certain group of data in order to investigate questionable phenomena. The multi-scale and multi-frequency data should be handled in a consistent manner. In addition, data collected from different channels (e.g. manual, meter reading, estimated) must be integrated.
- o The structure of the data model must respond to variable energy/environment parameters and future developments. As energy/environment issues are often related to social and political factors, the parameters involved in an analysis methodology could vary depending on the nature of the analysis. To ensure the flexibility of the data model, users must be able to customise data attributions when setting up a database.
- o In order to cope with different scales of energy/environment analysis, the data grouping and classification should be enabled by different viewpoints. For example, a building may comprise several zones and renewable energy systems at the same time. Further, the building may belong to an institution, which has many properties.
- o It is important to avoid unnecessary duplication of data in terms of the efficiency of information storage and maintenance.

The data model of the EEIS database has been designed on the basis of the relationship between an entity, energy/environmental factors and associated events. In the EEIS context, an entity is defined as an object that consumes/generates energy and has an environmental context mainly associated with energy action planning. An entity may therefore be a building, a wind farm, a photovoltaic panel, a vehicle and so on. As illustrated in Figure 4-1, an entity, whether it is real or virtual, has a relationship with several energy/environment events. An entity may have many metering points with different fuel types (e.g. gas, electricity, oil etc) being recorded at different frequencies.

The climate context affects the energy behaviour of an entity in terms of consumption/generation. Weather data may be shared by a number of entities. Conversely, since the sources of weather data are likely to be diverse (e.g. measured at a local or remote weather station, statistically processed etc.), an entity may also be related with several weather collections. Construction or energy system refurbishment will change the energy performance of a demand-side entity such as a building. This may happen occasionally or more frequently. A building can have its own indoor environment (i.e. temperature, humidity, CO_2 level etc) synchronised with energy use and corresponding to thermal comfort and air quality. It can also have its own time schedules regarding operation, production (in the case of an industrial property), occupancy interactions and so on. While gas emissions are related to energy consumption and fuel type, the location of the entity is an important factor since this will dictate the fuel mix used for electricity generation and therefore the real emissions.

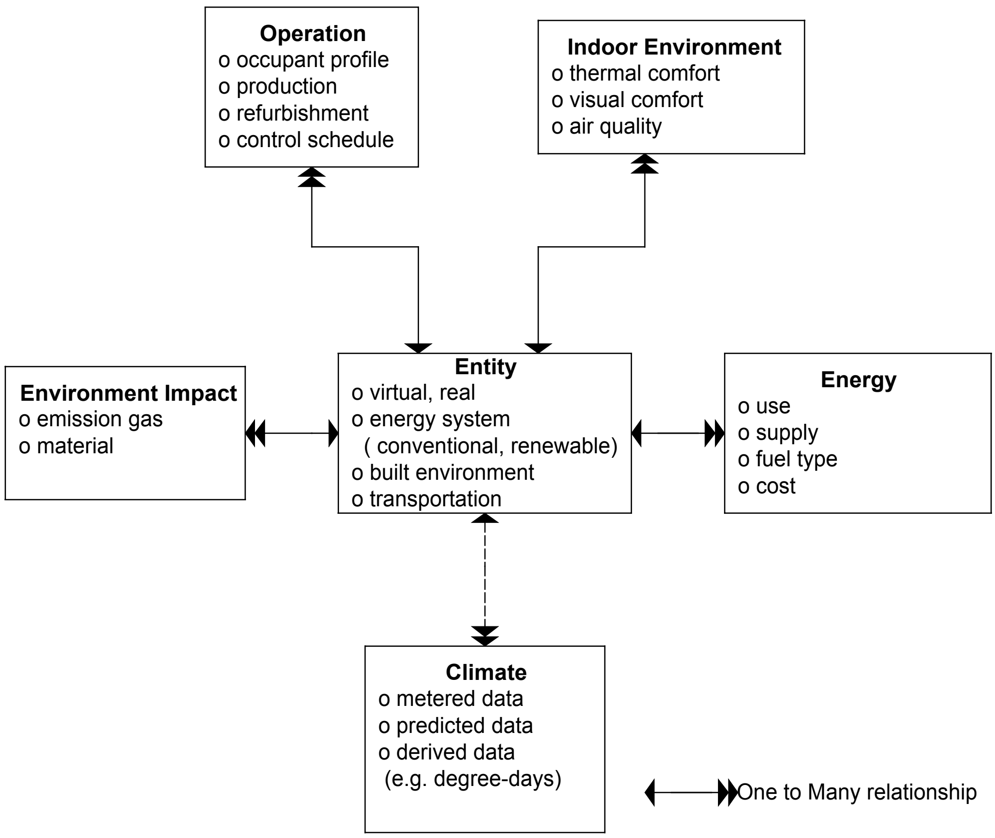


Figure 4-1 Conceptual data model illustrating elements and relationships within the EEIS system.

While the entity data element has attributes regarding the physical characteristics (e.g. location, function and type), the energy/environment and operational elements are dynamic. Energy/environment and operational data are linked to the entity by sharing the identifiers of the entity data. Such an entity-oriented relationship allows consistent data manipulation against various aspects of analysis. For example, the energy use of an entity can be synchronised with its indoor environment parameters. Both energy use data and indoor environment data are then integrated by using the entity identifier and time stamp.

An issue arises when handling dynamic data. The volume of time-based data is considerable when it comes to large-scale energy management. Should the data be recorded at high frequency, the data accumulation grows significantly. A huge volume of multi-frequency data is likely to affect database performance. Concerning DBMS performance, dynamic data may be divided into several parts according to frequency (e.g. half hourly, daily, monthly). However, such a separation gives rise to an inconsistent structure within an integrated analysis system that attempts to offer both strategic and tactical views. Since the data has to be selected from different tables, data manipulation and maintenance will become unnecessarily complicated. In addition, the requirement of the data model must meet multi-channel data sources, which usually involve different data frequencies (e.g. half-hourly meter reading and monthly energy bills).

It is important that the performance of the whole analysis process be taken into account as the analysis applications are independent from the database system. The performance of the DBMS can be achieved by developing efficient data processing models. For example, the data can be sorted by inserting a time tag into a data record and selecting the data according to the tag. Alternatively, the data aggregation can be made when requesting data. Whatever the frequency, the data can be sorted during the extraction process. There are two approaches to managing the data. One is to select data and process them within the analysis application. (This is discussed in Section 4.3). The other is to use the server's processor by issuing SQL statements. For example, the following SQL statement is a query for the daily sum of the gas use from half hourly monitored data. Using the 'GROUP BY' option, the data calculated on the server-side are given to the client-side (i.e. the analysis application).

```
SELECT m_id, m_item, datetime, SUM(value) from monitored  where (m_id='A062462363' ) and m_item
    ='gas' GROUP BY m_item, year( datetime ), month(datetime), dayofmonth(datetime);
```

The main difference between the two approaches relates to where the processing burden is imposed. In order to obtain desirable overall performance, the operating strategy must be taken into account as well as the structure of the data model.

Should the database be associated with real-time control so that the response time is critical, the performance of the database should be managed by redistributing the data to several locations. For example, the database could be divided into an operating database and a storage database. The operating database is usually required to manage data transactions in the short term (e.g. control signals, system malfunction detection etc). As the content of the operating database is always updated, data conversion from the operating database to the storage database has to be carried out at frequent intervals.

The attributes of the entity (including the sub-type entities) and other associated data elements are discussed in the following sub-sections as well as the definition of the physical data tables.

4.1.1 Entity

An entity represents a demand or supply system including buildings, cars, generators (e.g. conventional, CHP) and renewable energy systems (e.g. PV, wind turbines). Figure 4-2 illustrates the entity model. The entity must be unique in a database although it can be either real or virtual. A generic entity model is defined possessing the common attributes of both demand and supply side systems. The attributes of this entity model include a primary identifier, geographical location, clustering keys (entity type, data type, construction type, ownership), external references (grid reference, weather collection) and year built.

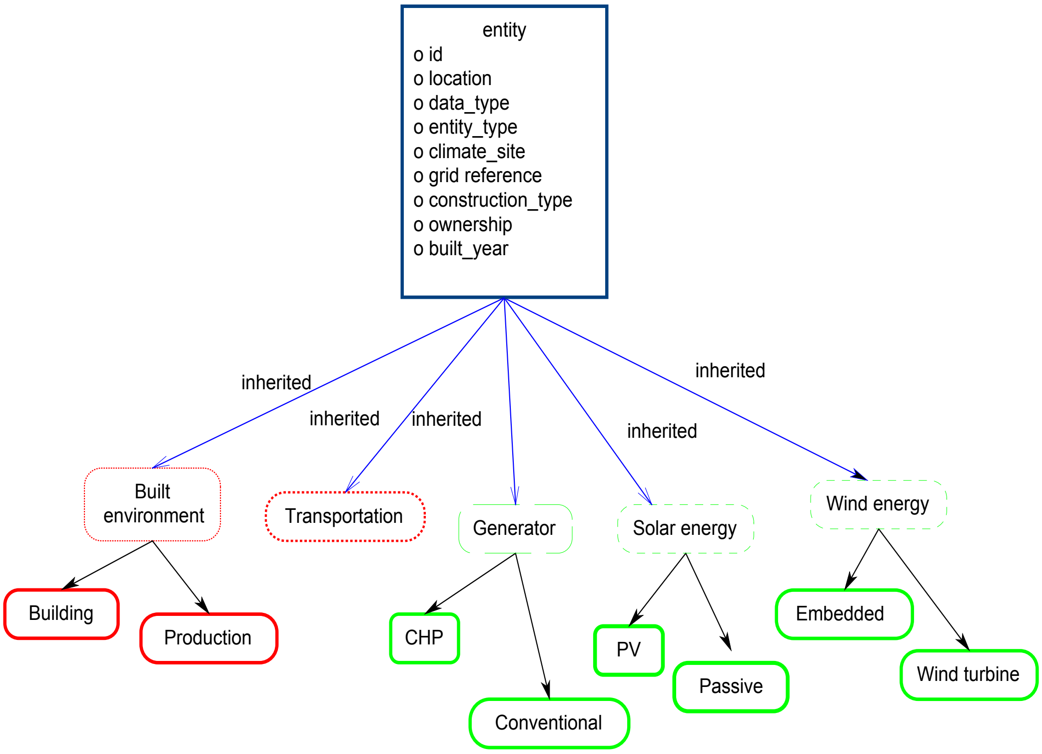


Figure 4-2 Entity model and inherited models.

The primary identifier is a unique reference code for identification to be used in other data tables as a linking key. The location of the entity is essential to identify the distribution of the entities in a broad area. Geographical location can be specified by postal information (i.e. address and post-code), while GIS reference code provides more precise x-y co-ordination of the entity. A data type is a clustering key defining real demand, virtual demand, real supply and virtual supply. The dynamic data (e.g. energy use and indoor environmental condition) associated with a virtual entity are virtual while the data associated with a real entity may be real (i.e. metered) or virtual (i.e. simulated or statistically estimated). Grid reference identifies the grid location where the entity is placed. Through this grid reference, multiple demand/supply entities can be grouped in support of a specific analysis such as demand/supply matching.

Table 4-1 shows the definition of the entity table. The items 'sort_code_1' and 'sort_code_2' are user-definable fields. This allows users to define entity attributes according to their particular purpose (e.g. political, social and operational issues).

Table 4-1 Definition of entity data table.

Attribute name	*Data Format*	*Primary Key*	*Description*
Ref	char(20)	PRI	Unique primary identifier of an entity
name	char(20)		Name of the entity
entity_type	char(4)		Type of the entity on the basis of function
sort_code_1	char(4)		User definable code
sort_code_2	char(4)		User definable code
data_type	char(4)		Data original source (real or virtual)
add_lin1	char(30)		Postal address line 1
add_lin2	char(30)		Postal address line 2
add_lin3	char(30)		Postal address line 3
post_code	char(10)		Post code in the address
district	char(4)		Name of district the entity is located in
gis_xref	decimal(10,2)		X value on GIS coordination
gis_yref	decimal(10,2)		Y value on GIS coordination
grid_ref	char(10)		Micro-grid reference the entity is connected to
construction_type	char(4)		Structural characteristics
ownership	char(10)		Ownership
climate_site	char(10)		Climate site
built_date	date		Date of construction

The attributes of the entity are inherited by sub-type objects such as building, vehicles, renewable energy systems etc. These sub-types will possess the attributes of the parent entity, but may also have additional attributes that are specific to the sub-type. This structure will bring advantages:

- consistency while integrating different energy systems in the same table;
- addition of new systems without changing existing models; and
- efficiency in data management by avoiding redundancy.

In XML, the inheritance of the common attributions in the entity data model to the child-entity (e.g. building, PV etc) can be implemented in a data structure. An example of the definition for a PV system data model is illustrated as below.

```xml
<!xml version="1.0"? >
<pv_system>
    <entity>
        <ref>  jwpv120021    </ref>
        <name> Roof mounted prototype </name>
         <entity_type> PV </entity_type>
        <data_type> SV </data_type>
        <address>
             <add_lin1> James Weir 24 Montrose St.</add_lin1>
            <add_lin2> 24 Montrose St.       </add_lin2>
            <add_lin3> Glasgow           </add_lin3>
           <post_code> DS0 123    </post_code>
           <district> Scotland </district>
        </address>
         <gis>
           <gis_xref> 260909 </gis_xref>
           <gis_yref>668262 </gis_yref>
         </gis>
         <ownership> Strath_uni </ownership>
         <climate_site> HWS </climate_site>
     </entity>
    <installer> ESRU </installer>
    <tilt_surface> 60 </tilt_surface>
    <orientation> 40 </orientation>
    <tracking_type> SAX</tracking_type>
</pv_system>
```

In a SQL-compliant database, it is implemented by sharing the primary key identifier (i.e. ‘ref’). In terms of the database performance, data query statements are likely to get complex when the attributes of the entity and those of sub-types are simultaneously required. This may affect the efficiency of retrieval.

As the definition of the entity data model is designed to reflect various energy demand/supply systems including the future possible systems that have their own specifications, the data model for the child entities can be defined by inheriting this common model. In this study, the building data model as a representative demand-side entity and two renewable energy systems (i.e. photovoltaic and wind turbine) as representative supply-side systems were implemented for the demonstration of the child-entity data model.

4.1.2 Building

Buildings are the main objects of demand side analyses within the EEIS. As a building usually comprises several spaces, a space is the unit entity. In the context of the EEIS, a building entity is associated with an Energy Accountable Centre (EAC) (DETR 1998). Figure 4-3 shows the building scale and energy metering structure. The scale of the entity is likely to depend on the energy data availability. Should energy be metered for a single building by means of main metering, the building would be regarded as a building entity. Should energy be metered for zones within a building by sub-metering, each zone would be a building entity. In the case of a single energy meter covering several buildings, the group of buildings are defined as a building entity. Therefore, a building entity could be a zone, a building or several buildings (i.e an entire estate).

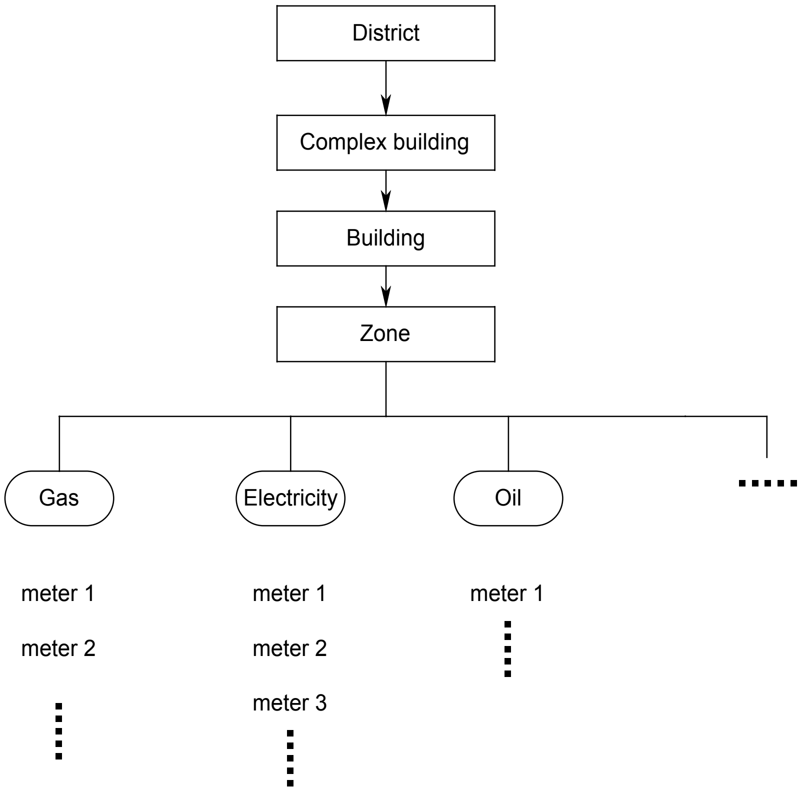


Figure 4-3 Scale of building entity and energy metering.

Table 4-2 Definition of building data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
Ref	char(20)	PRI	Reference identifier of entity
building_ref	char(20)		Reference identifier of upper level building
exposed_area	decimal(8,1)		Exposed area (m^2)
volume	decimal(8,1)		Volume of building (m^3)
flr_area	decimal(8,1)		Floor area (m^2)
ht_volume	decimal(8,1)		Heating volume (m^3)
ht_flr_area	decimal(8,1)		Heating floor area (m^2)
transp_area	decimal(8,1)		Transparent area (e.g. window) (m^2)
transp_type	char(4)		Transparent type
opaque_area	decimal(8,1)		Opaque area (m^2)
opaque_type	char(4)		Opaque type

system_type	char(4)	Energy system type (e.g. HVAC, floor heating)
occupancy_ref	char(10)	Occupancy reference identifier
operation_ref	char(10)	Operarion reference identifier

The building entity model contains summarised information. It is not necessary to hold detailed information for the building because such information is usually held in the databases of related departments (or organisations) and may be related to by using an identifier or foreign key. Once an entity has been defined its records may remain unchanged unless the construction specification is significantly changed (e.g. through a structural renovation). If significant structural changes occur, users may either update the record or create a new entity record.

As an entire building usually comprises several sub-set building entities, the reference identifier of the building is required when an analysis is carried out at the whole building level. The characteristics of construction such as exposure, floor area, volume, heating area and heating volume are specified in the table. The reference identifiers associated with occupancy and operation are also included.

4.1.3 Photovoltaic Systems

The photovoltaic (PV) system data model was established as a sub-type entity of a supply-side renewable system. The PV data model was designed to reflect the input parameters of the demand/supply matching program, MERIT (Born 2001, Smith 2002). It is difficult to define attributes in a data table because a PV system is constructed with several sub-systems, some of which are optional. As illustrated in Figure 4-4, one main data table, ‘PV system’, contains the basic information of the PV component and reference identifiers link with three sub-models: PV panel, heat recovery and inverter.

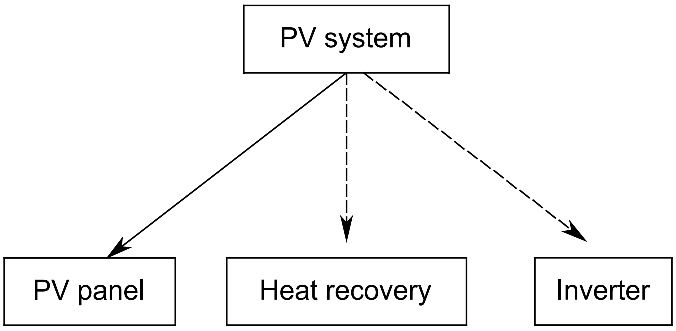


Figure 4-4Architecture of PV data model.

The reference identifier of 'PV system' is used to link to an entity that has general information (e.g. location, data type etc). A PV system can be virtually assembled from PV panels, heat recovery device and inverter through reference identifiers (i.e. panel_ref, heat_recover_ref, and inverter_ref). Surface tilt, orientation and tracking type are defined by the user. The data within the panel data table exists to calculate the power output of the PV cell, which can be obtained from manufacturers' specifications.

Table 4-3 Definition of PV system data table.

Attribute name	*Data Format*	*Primary Key*	*Description*
Ref	char(20)	PRI	Reference identifier of entity
installer	char(20)		Installer
panel_ref	char(12)		Reference identifier of panel
tilt_surface	decimal(7,2)		Tilt of surface (degree from horizontal)
orientation	decimal(7,2)		Orientation (degree from North)
tracking_type	char(4)		Tracking type (single axis /double axis/tilt opt)
inverter_ref	char(12)		Reference identifier of inverter
heat_recover_ref	Char(12)		Reference identifier of heat recovery

Table 4-4 Definition of inverter data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
inverter_ref	char(12)	PRI	Primary id of inverter
name	char(20)		Name of inverter
manufacturer	char(20)		Manufacturer
rated_power	decimal(7,2)		Rated power (W)
efficiency	decimal(7,2)		Efficiency (%)

Table 4-5 Definition of PV panel data table.

Attribute name	*Data Format*	*Primary Key*	*Description*
panel_ref	char(12)	PRI	Primary Identifier of pannel
name	char(20)		Name of pannel
manufacturer	char(20)		Manufacturer
cell_type	char(4)		Mono-crystalline/poly-crystalline/amorphous
no_of_panels	Int(3)		Number of pannels
open_circuit_voltage	decimal(7,2)		Open circuit voltage(V)
short_circuit_current	decimal(7,2)		Short circuit currence(A)
max_power_voltage	decimal(7,2)		Max power point voltage(V)
max_power_current	decimal(7,2)		Max power point current (A)
temp_at_stc	decimal(7,2)		Temperature at STC (deg c)
ins_at_stc	decimal(7,2)		Insolation at STC (W/m^2)
no_of_series_connected_cells	int(4)		Number of series connected cells
no_of_parallel_branches	int(4)		Number of parallel branches
width	decimal(7,2)		Panel width (m)
height	decimal(7,2)		Panel height (m)
nominal_peak_power	decimal(7,2)		Nominal peak power (W)

Table 4-6 Definition of heat recovery data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
heat_recover_ref	char(12)	PRI	Primary id of heat recovery
name	char(20)		Name of heat recovery

gap_width	decimal(7,2)	Gap width
facet_width	decimal(7,2)	Facet width
facet_length	decimal(7,2)	Facet length
emissivity_wall	decimal(7,2)	Emissivity of wall
emissivity_pv	decimal(7,2)	Emissivity of PV
convection_type	char(4)	Natural /forced
flow_rate	decimal(7,2)	If convection type =forced

4.1.4 Wind Turbine Systems

The wind power system data model represents a sub-type entity of a supply-side renewable system. The wind power system model was designed to reflect the input parameters of the demand/supply matching program, MERIT. A wind power system can be defined with two data models: the general information of a wind regime and the technical information of the turbines. The definition of these two models is illustrated in Figures 4-7 and 4-8. The wind power system table contains configuration information (i.e. entity identifier, name, installer and turbine reference ID) and parameters such as height, orientation, surface roughness, wind speed measurement type and turbine type. On the other hand, the turbine data table accommodates mechanical characteristics (i.e. turbine power curve, air density, swept area and power factor) usually available from manufacturers' data sheets. The data are stored in a set of xy figures (i.e. power(kW) versus wind (m/s), which are used to create a characteristic curve within an analysis module.

Table 4-7 Definition of wind power system data table.

Attribute Name	*Data Format*	*Primary key*	*Description*
Ref	char(25)	PRI	Reference identifier of entity
name	char(30)		Name of wind power system
Installer	char(25)		Installer
turbine_ref	char(25)		Reference identifier of wind turbine

Num_turbines	int(3)	The number of wind turbines
Orientation	decimal(7,2)	Orientation only for ducted type wind turbine
Height	decimal(7,2)	Height
surface_roughness	char(4)	Type of the surface roughness
Wsm_typ	char(4)	Type of wind speed measurement related to calibration of wind power
turbine_type	char(4)	Type of wind turbine (e.g. ducted, rotor blade)

Table 4-8 Definition of wind turbine data table.

Attribute Name	*Data Format*	*Primary key*	*Description*
turbine_ref	char(20)	PRI	Primary id of heat recovery
name	char(20)		Name of wind turbine
manufacturer	char(20)		Manufacturer
powercurve_po	Text		Power curve for power output Air density
Air_density	decimal(7,2)		Air density
swept_area	decimal(7,2)		Swept area
power_factor	decimal(7,2)		

4.1.5 Energy

In order to analyse the energy consumption/generating characteristics and economic aspects, the energy and cost-related data must be recorded. One energy record contains meter identification, metered period, load type, fuel type, consumption and cost (i.e. relevant tariff rates). An energy record is identified via an entity primary identifier, meter ID, energy type and time period. The 'load_type' indicates the energy consumption purpose (e.g. space heating, hot water, lighting etc.). This data item is used for relatively detailed energy analysis (e.g. energy use breakdown and profiles according to demand types). Meanwhile, 'm-number' is the identifier used by both the Gas and Electricity industries. The m-number is critical for identification of the point of supply. It is the identifier of the end of the pipework in gas, and cables for electricity. Since it is unique and constant, the number makes it possible to track energy use regardless of supplier. In the UK it is known correctly as the Mnumber for gas metering. For electricity metering, it is known as the Meter Point Administration Number (MPAN), which identifies the distribution company and the location of the metering point with supplementary data such as metering information, profile class, time-switch code, line loss factor etc.

Energy consumption is the integral of power over time. The frequency of energy meter readings varies with the reading activity sometimes occurring irregularly, and all meters not metered simultaneously. Therefore, recording the period of energy consumption is essential. The 'from_datetime' and 'to_datetime' fields are used for this purpose.

Depending on the fuel type, the unit of the energy consumption may be different. For instance, gas meters use a volume-based unit, which must be adjusted to account for the fact that volume is affected by pressure. The corrected volume is then converted to an energy unit using the calorific value. In order to keep the consistency of the quantitative analysis, all consumption/generating data are converted to kWh.

Dial_1 and dial_2 are used to reflect the different tariffs between on-peak and off-peak times in electricity consumption. The '1' extension refers to the first meter reading, generally the day rate. There will be similar readings for the night meter generally having the suffix '2', i.e. pf2, md2 etc. Total consumption is calculated by converting the sum of advanced_1 and advanced_2 to a uniform unit (kWh). The 'Avail' field is the authorised capacity (kVA) of the electrical installation. The fields of 'md1' and 'md2' are the highest average demand (kW) recorded in a 30 minute period in a month. The fields 'pf1' and 'pf2' contain the average power factor recorded during the period. Power factor relates to how efficiently electricity is used on site. Certain types of equipment cause a poor power factor, which reduces the capacity of the network to supply power. Distribution companies can charge customers for this through power factor charges.

The relationship between current and power in an AC circuit is expressed by

Power = Voltage x Current x Power Factor

or kW = kVA x Power Factor

Table 4-9 Definition of energy data table.

Attribute name	*Data Format*	*Primary Key*	*Description*
ref	char(25)	PRI	Reference ID of an entity
meter_id	char(15)	PRI	ID code of meter
m_number	char(25)		Unique number identifying the point of supply
supplier	char(4)		Energy supplier
Fuel_type	char(5)	PRI	Type of energy source (e.g. electricity, gas, oil etc)
Load_type	char(5)		Type of load energy is consumed for. (e.g. space heating, catering hot water, lighting etc).
ac_no	char(20)		Account number of financial aspect database.
Avail	int(8)		Authorized capacity kVA of the electrical installation.
From_datetime	Datetime	PRI	Starting time of the period energy was consumed. Date format must be YYYY-MM-DD HH:MM:SS.
to_datetime	Datetime	PRI	Ending date of the period energy was consumed. Date format must be YYYY-MM-DD HH:MM:SS
Dial_1	int(12)		Meter reading
advance1	int(12)		Actual units used (current dial_1 - previous dial_1)
Md1	decimal(10,2)		The highest average demand (kW) recorded in a 30 minute period in a month.
Pf1	decimal(5,4)		Power factor
Dial_2	int(12)		Meter reading
advance2	int(12)		Actual units used (current dial_2 - previous dial_2)

Md2	decimal(6,1)	The highest average demand (kW) recorded in a 30 minute period in a month.
Pf2	decimal(6,4)	Power factor
Cost	decimal(20,2)	Total cost of energy consumption
Tot	decimal(20,2)	Total energy consumption over the period between from from_datetime to to_datetime. Unit is KWh.
r_type	char(4)	Type of meter reading(e.g. estimated, self reading).
tar_id	char(4)	Type of tariff.

The power factor is a number between 0 and 1 and defined as the cosine of the phase angle between the voltage and the current. The lower the power factor, the bigger the wires needed to supply the customer with a given amount of energy in a given period. The power factor of an electrical installation can affect the cost of electricity. In other words, an electricity consumer may want to improve the power factor of their electricity consuming equipment in order to pay less. This is usually only appropriate for larger commercial and industrial electricity users.

To assess economic energy use, cost-related data is recorded (i.e. ’cost’ and ‘tar_id’). The field ‘r_type’ indicates how the data record is collected (e.g. customer reading, estimated or automatic sensing system).

4.1.6 Environment

Climate

An entity may be related to several types of climate data. These data are either measured on-site or obtained from the Meteorological Office. Solar radiation, temperature, relative humidity, wind speed and wind direction are generally used in building energy management and building modelling activities. However, the items and formats of weather collections are variable depending on the analysis methods and software programs. The integration of various weather data formats is a rising issue. For example, Crawley et al (1999) made an attempt to develop a generalised weather data format for different building energy simulation programs.

Table 4-10 Definition of climate data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
Climate_site	char(10)	PRI	Key code indicating the site covered by this climate data.
Climate_code	char(5)	PRI	Type code of climate data (e.g. daily average, hourly average, instance etc).
Date	Date	PRI	Date stamp (YYYY-MM-DD)
Time	Time	PRI	Time stamp (HH:MM:SS)
Item	char(8)	PRI	Item of weather (e.g. air temperature, humidity, wind velocity, etc). unit of items refers to code look up table.
Value	decimal(10,3)		Data value. Unit depends on the item.

To deal with climate data in a flexible manner within the EEIS, the climate data table has been designed to have an open structure rather than a fixed format. To implement the open structure concept, the climate table uses an indicating key code field. Each climate data element is assigned a 'climate_code' to indicate the nature of the data. 'Climate_code' gives information on how the data is generated (e.g. measured, estimated statistically and so on). The 'item' field denotes the climate item type (e.g. temperature, relative humidity, solar radiation etc).

Degree-days are a weather severity index traditionally used for energy management. These data can be input from a monthly publication or the data can be derived from the temperature item within the climate table. Degree-days vary according to a base temperature, which is dependent on the location and, possibly, micro-climate effects (Energy Efficiency Office 1993). The 'dd_code' field identifies the required calculation parameters. The 'type_dd' field indicates the type of degree-days according to the period (e.g. daily or monthly). The 'climate_site' field is the key code for the deriving process between the climate table and the degree-days table. Table 4-11 shows the definition of the degree-days data table.

Table 4-11 Definition of degree-days data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
dd_code	char(10)	PRI	Code identifying the calculation of degree days (e.g. region, base temperature etc)
type_dd	char(10)	PRI	Type of degree days according to the period (e.g. daily, monthly)
Date	date	PRI	Date time stamp (YYYY-MM-DD)
Dd	int(8)	PRI	Number of degree days
Climate_site	char(10)		Key code indicating the site covered by this climate data.

Indoor Environment Data

Indoor environment data are mostly associated with buildings. As with the 'climate data' table, the 'indoor_climate' table has an open structure to deal with various indoor climate factors (e.g. temperature, humidity, CO, CO_2 etc). The table uses the indicating key codes 'ic_code' and 'ic_item', which are registered in the look-up table. The definition of the indoor climate data table is shown in Table 4-12.

Gaseous Emission Data

The 'gas emission' data table holds emission factors. The gas emission can be estimated on the basis of fuel type, the burning technology employed and the geographical location of an entity. A given fuel type gives rise to several emissions (i.e. CO_2, CH_4, NO_2, N_2O, SOx etc) and there are different approaches to estimation (Munro 1997). The 'gas emission code' field is related to the estimation methods. The emission factors are stored along with a time stamp because the factors may be updated on a temporal basis. The definition of the gaseous emission data table is illustrated in Table 4-13.

Table 4-12 Definition of indoor climate data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
Ref	char(25)	PRI	Reference ID code of the entity
ic_code	char(5)	PRI	Type of indoor climate data (e.g. daily average, hourly average, instance etc) .
Date	Date	PRI	Date time stamp (YYYY-MM-DD)
Time	Time	PRI	Time stamp (HH:MM:SS)
ic_item	char(8)	PRI	Items of indoor climate (e.g. air temperature, humidity, wind velocity, CO, CO_2 etc). Unit refers to code look up table.
ic_value	decimal(10,3)		Data value. Unit depends on the item.

Table 4-13 Definition of gaseous emission factors data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
region_code	char(5)	PRI	Code of region
gas_emission_code	char(5)	PRI	Code of estimation method
date	date	PRI	Date time stamp (YYYY-MM-DD)
energy_type	char(5)	PRI	Type of energy(e.g. electricity, gas, etc)
gas_type	char(5)	PRI	Type of gas (e.g. e.g.CO_2, CH_4, NO_2, N_2O, SOX, etc)
Factor	decimal(12,2)		Value of Gaseous emission factor

4.1.7 Events and Operation

Refurbishment

A building can undergo a series of events such as refurbishment (e.g. replacement of single by double glazing) or the installation of a new energy system (e.g. adopting renewable energy components). The events of a building are recorded historically. The content of the refurbishment data table is illustrated in Table 4-14.

Table 4-14 Definition of refurbishment data table.

Attribute Name	*Data Format*	*Primary Key*	*Description*
Ref	char(18)	PRI	Reference ID code of the entity
event_code	char(10)	PRI	Code of refurbishment type.
Date	Date	PRI	Date time stamp YYYY-MM-DD
Content	char(100)		Content of refurbishment

Operation

This data table (Table 4-15) is for non-climate factors affecting energy consumption. These factors involve time-dependent, energy-related activities such as occupant profiles, energy system operating hours, production (if the entity is associated with an industrial facility) and other relevant information.

Table 4-15 Definition of operation data table.

Column name	*Data type*	*Primary Key*	*Description*
Ref	char(25)	PRI	Reference ID code of the entity
operation_code	char(10)	PRI	Code of operation type (e.g. occupant Profile, operating days(or hours))
Date	Date	PRI	Date time stamp (YYYY-MM-DD)

Time	Time		Time stamp (HH:MM:SS)
op_value		PRI	Value of operating factor

4.1.8 Look-up Data

The look-up table contains reference information on the codes used in all other tables. To deliver information to users, the machine-based terms must be translated. The database management applications require the reference information for the translation. Administrating the codes of each table centrally provides an efficient approach to system maintenance and operation.

Within the EEIS, a 'look-up' data item provides the description of the codes used in the data tables. Generally, the data of each table is encoded and stored in the database to reduce the physical volume. Encoding data is used only within the database system. When it comes to the user interface, the data has to be decoded. The look-up data is used by the user interface application to decode the data. Therefore, the look-up data is related to those data tables that possess encoded data. Appendix C gives an example of a look-up data table. The content of the look-up data table is given in Table 4-16.

Table 4-16 Definition of look-up data table.

Attribute Name	*Data Format*	*Key*	*Description*
column_name	char(30)	PRI	Field name in tables
code	char(5)	PRI	Code used in the column (field)
name	char(30)	PRI	Name
description			Description of the code.

4.2 Scope Management

The EEIS analysis and reporting modules provide integration of the following information:

- summary reports on information on energy use and environment impact relating to sets of entities at different scales (e.g. national, regional, city district, street or house);
- an individual entity's static information (e.g. location, ownership and type);
- profile analysis to compare the time-varying nature of two entities (e.g. offices versus houses) or periods (e.g. 2004 versus 2000-3);
- more detailed analysis such as classification, regression, modelling and demand/supply matching;
- monitoring energy demand/supply and tracking problematic entities; and
- database maintenance (e.g. statistics on available data resources).

While the data dealt with in the EEIS is large in terms of the potential scale and diversity, the entities of interest must be defined by decision-makers for a specific analysis. Figure 4-5, for example, illustrates domains of interest regarding demand/supply issues.

The potential for a certain form of renewable energy (e.g. onshore wind farms) in a region (e.g. Scotland) is presented via GIS-based maps. The detailed information on an entity (e.g. a wind turbine within a wind farm) can then be retrieved by the user. Meantime, the demand entities distributed in a rural area (e.g. Highland Region) may be studied to identify the characteristics of energy use. A micro-grid in a rural area could be defined as the active scope comprising, for example, wind turbines and to loads. A demand/supply matching analysis may then be undertaken for this scope. Alternatively, the scope might target a single house with a PV system so that the demand/supply matching is at the small scale.

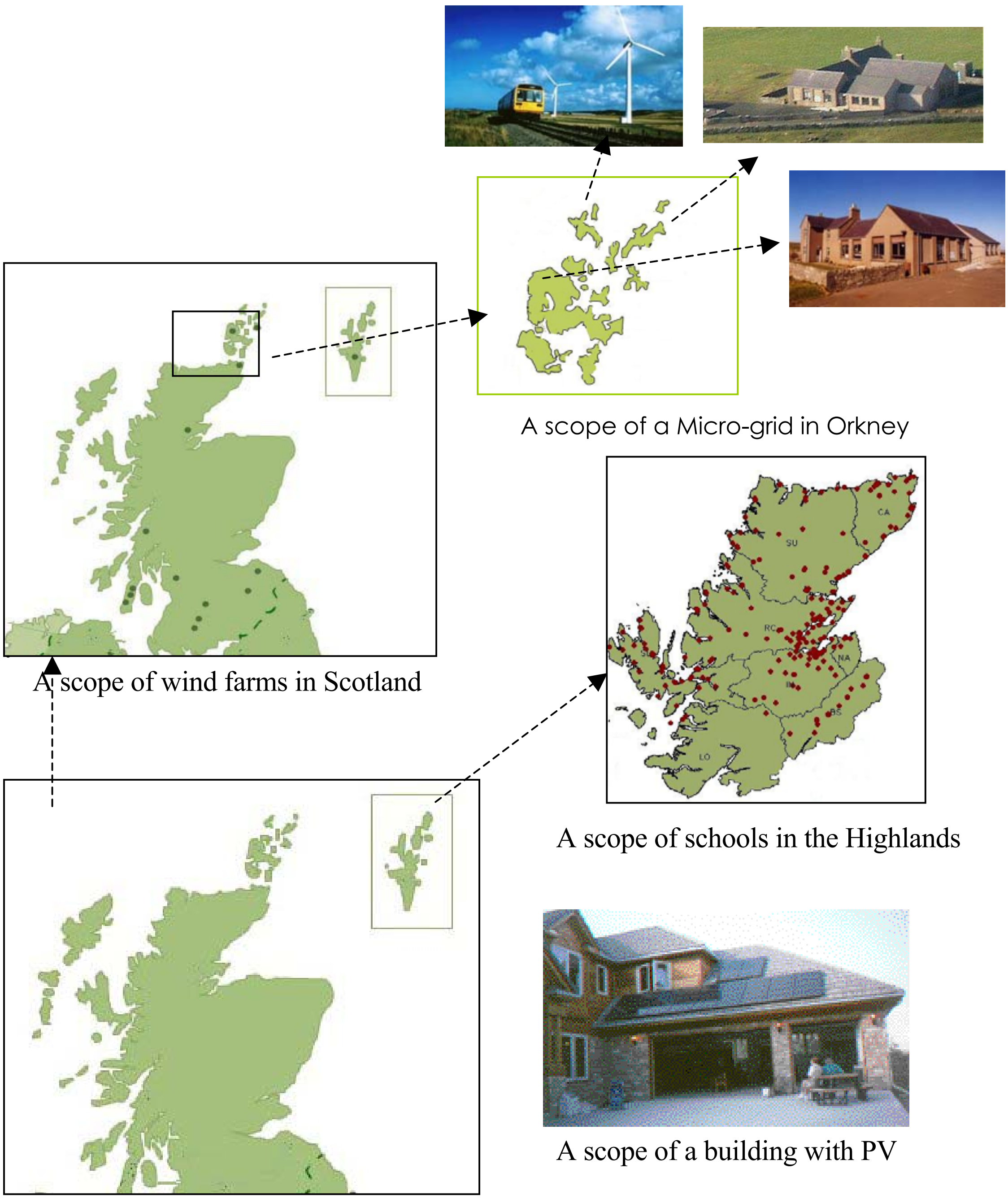


Figure 4-5 Scopes involving demand/supply entities at different scales.

Information processing in the EEIS is based on data comprised of static descriptors and dynamic data (e.g. energy use, weather parameters and operational aspects). Sometimes it is necessary to track down the data domain associated with problems discovered from a strategic analysis. It is not trivial for users to understand the database and manipulate the data. Users require a support mechanism that enables them to extract useful information from data.

Within EnTrack, a scope was defined in terms of energy consumption period, fuel type, buildings type etc. Mixing up the static data (i.e. entities) and dynamic data (i.e. energy consumption, weather) in specifying a scope give rise to unnecessary complexity. For example, when users wish to make another report for the same group of buildings but for a different period, they have to defining a new scope. When it comes to the analyses associated with indoor/outdoor environment factors, managing scopes becomes complex and inefficient.

The crucial drawback is that the integrated tactical/strategic analysis cannot be implemented because it is not possible to undertake multiple analyses without defining their scopes in advance. The operational mechanism for defining scope must be flexible and portable to allow multi-variant and multi-scale analyses to be undertaken in an efficient manner.

In order to address this issue, an efficient data filtering mechanism is required. The concept of 'scope' has been established in this study. The difference with EnTrack (Evans 2000) is that a scope as a data view comprises only the set of entities of interest (e.g. a building and its renewable supply component, or all buildings within a local authority's estate). The entities for a scope are selected according to sorting criteria, which may be a building type, its geographical location or any other describing parameter.

Once a scope has been defined, the scope can be used as input to various analysis techniques along with related dynamic data models. Combining a scope with other dynamic data models defines a Data Aspect Model (DAM) as described in Section 4.3 where the EEIS's analysis process model is considered. This portable data mechanism makes it easy to manage the integration of tactical/strategic analysis. It can be implemented in a coherent manner to undertake different analyses (e.g. multi-scales profiles from daily statistics to yearly statistics, comparisons of energy consumption/gas emissions over different periods) using a single scope definition.

In practice, this flexible data filtering mechanism is facilitated by adopting the relational DBMS model. A simple scope data model can be made using SQL statements. This scope model consists of a scope name and an SQL-formed conditional statement corresponding to a 'building' data set. The conditional statement is exploited when completing an SQL statement to request data. An example of defining scopes with SQL statements is given below. 'James Weir' is the name of the scope, while the statements of (entity.ref like 'JA%'), (origin_data='DR') and (name ='James Weir Building') are the conditions of the scope.

```
James Weir
( entity.ref  like 'JA%' ) and (  origin_data='DR' ) and (  name ='James Weir Building' )
John Anderson Campus
( entity.ref like '%' ) and (  origin_data='DR' ) and (  district ='JA')
```

Users may wish to make several scopes for a certain analysis. Further, they may want to reuse scopes previously defined. The scope data set is stored in a file with a URL, which is located in either a local directory or the Internet. The file containing the scope definitions is managed by users, not by the database system, which means that it is not necessary to hold the scope data set at the server-side of the EEIS database system. Users can define their own scopes and store them in either their local or networked file system.

To enhance user interactivity with the EEIS database, it is necessary to provide users with the ability to scan through maps or graphical images to focus on particular regions or a certain entity type spread throughout a broad geographical area. A user interactive scope map model has been developed. This allows the spatial analysis of the entities of interest at any resolution.

4.2.1 Interactive Scope Map Model

An interactive scope map interface system has been developed, which offers a visual tool for users to handle scopes. Users can move from one scope of interest to another via image maps. A map model consists of scope information and a corresponding image map that has been selected to represent the scope (e.g. a regional map, a street map or a building plan). The scope information the map represents is sent to the EEIS database system, while the image map provides users with views representing the available scopes. The data parameters indicating the corresponding scope are passed to other processes working within the EEIS. In other words, the interface is a visual front-end to the EEIS database. It is not necessary for the images to be maps; any graphic image can be used to represent a scope (e.g. photos of buildings, symbolic images, diagrams etc).

The basic idea is taken from HTML image mapping where an image map is a clickable image used to link an area on an image to another HTML page. In general, an image is a graphic file (e.g. GIF, JPG or PNG). An image can have several areas comprising three basic shapes: circles, rectangles and polygons. These areas are hotspots that, when selected, invoke an event.

Since the map model is independent of the EEIS structure, it is possible to make the maps generally accessible. The sensitised map on the user-side (user interface), and SQL statement generator on the DBMS server-side (system interface), can be implemented separately. This flexibility allows the scope map interface to be exploited in any user interface type (i.e. Web based or standalone).

A scope map interface consists of a map viewer, a map object and a SQL statement generator (i.e. a client program of the DBMS; see Figure 4-6). The map viewer shows image maps to users on the screen and senses the user's mouse position on the map. The position of the mouse is passed to the SQL statement generator. When a scope is selected, the SQL statement generator reads the parameters of the condition on the current scope map appearing on the map viewer and inserts a SQL statement as part of a query statement defining the condition of the query (i.e. the part statement starting with ‘WHERE’). Once the condition statement has been composed, it is used for other procedures (e.g. analysis, retrieving etc) that require the information on the range of the scope.

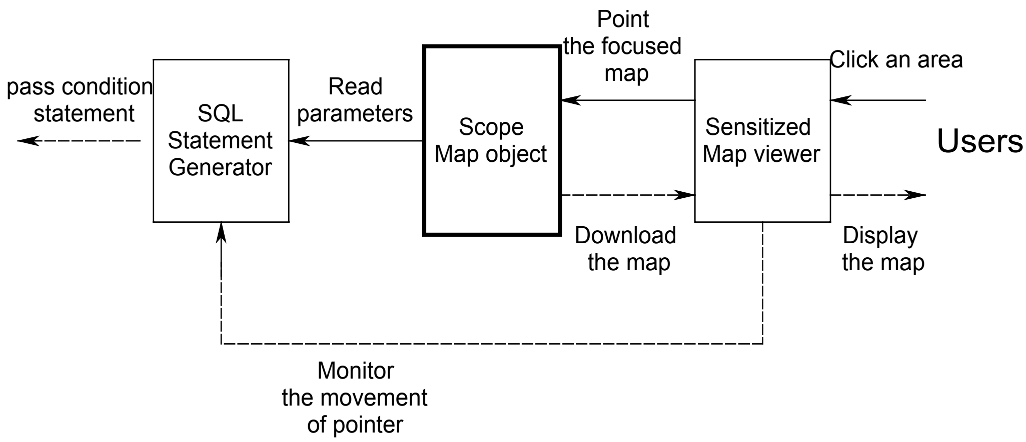


Figure 4-6 The mechanism of the interactive map user interface.

The scope map model possesses relevant information used for both the map viewer and the SQL statement creator. A map object has several elements as follows.

- Name of map: this is associated to the scope that the map represents.
- Name of database: indicates the database to which this scope belongs.
- Condition of data-set for the scope: defines the condition for selecting the data corresponding to a scope from the EEIS database.
- Image file for map: containing the map or a suitable symbolic image.
- Sub map pointers: hotspots linking to sub-scope maps under the current map. By clicking on a pointer, the scope map is moved down or up.

Figure 4-7 illustrates the elements of the map object and their relationship to the map viewer and SQL statement. At the user side, the map viewer requires information on the name of the map, the image file for the map and any sub-map pointer(s), while the information on ‘name of database’ and ‘condition of data set’ are used to create SQL statements at the system-side. The map object containing the information can be implemented in electronic media such as HTML or XML.

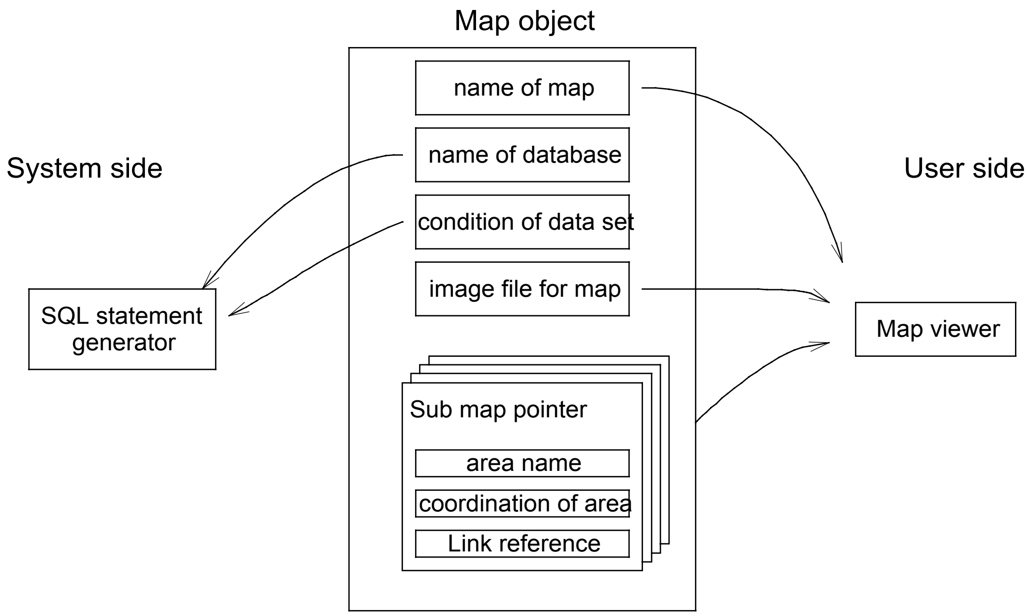


Figure 4-7 The elements of an object of the sensitised map.

4.2.2 Implementation

The implementation has been made in an HTML format. Additionally, a XML-based model has been attempted. Figure 4-8 shows an example of the implementations of the map object in HTML. In this example, because HTML does not allow self-defined tags, the tag '<!linkdatabase>' has been introduced for the SQL statement generator on the DBMS side. While it is read by the SQL statement generator, the tag <!linkdatabase> is regarded as a comment statement by the HTML document viewer that acts as the sensitised map viewer here.

read by SQL statement generator in DBMS side

```
<!linkdatabase database="training" district="AB"  add_name="aberdeenshire">

<html>
<head>
<TITLE>Aberdeenshire </TITLE>
<meta name="database" content=" ">
</head>

<img  src="aberdeenshire.gif" usemap="#aberdeenshire" border="0"  >
<AP>
<MAP NAME="Aberdeenshire">
<AREA SHAPE=POLY
   COORDS="580,315,545,315,493,319,495,290,573,291,580,315"
   HREF="./turrif/turrif.html" ALT="Turrif">
<AREA SHAPE=POLY
   COORDS="517,196,459,190,456,229,471,251,507,250,581,234,573,204,517,197"
    HREF="./aberdeen_city/aberdeen_city.html" ALT="Aberdeen city ">
</map>
</body>
</html>
```

read by sensitized Map viewer in user side

Figure 4-8 An example of the implementations of the scope map model in HTML.

In the <!linkdatabase> statement, the condition of the scope is defined as district code = ‘AB’ and add_name =’aberdeenshire’ in the database of ‘training’. The scope map contains two sub-scopes defined in ‘turriff/turriff.html’ and ‘aberdeen_city /aberdeen_city.html’.

Although the HTML format offers a useful facility to make the sensitised map, it is still not suitable for communicating with the system interface. In fact, a specifically designed file parser is required to read part of the SQL query condition in the HTML file. The parser program reads a stream of the <!linkdatabase> tag located at the first line in the HTML-based scope map file before it tokenises the stream to match the values to the corresponding parameters. While this approach is simple to implement, it is not de facto in multi-media data communication. In addition, there are limitations in managing complex parameter conditions.

To overcome this incompleteness, XML could be an alternative. Fig 4-9 shows the XML-based implementation. In this study, the scope maps were created mainly in the HTML format because XML applications are not widely available at present. As the scope maps are implemented in HTML/XML format, it is possible to locate the files of the scope maps in a URL. The scope map files can be accessed and viewed by any user interface system whether a Web-based interface (i.e. a browser) or a standalone application. Figures 4-10 show an example of a Java applet deploying the same scope map implemented in HTML files equivalent to the HTML-based scope map model in Figure 4-8. This accessibility improves the multi-user interface aspect of the EEIS, which is a crucial system requirement as described in Chapter 3.

```
<?xml version="1.0"?>

<scope_map>

     <Name>Map of Aberdeenshire</Name>

     <Description>
          This is a map object of Aberdeenshire for EEIS.
     </Description>

     <linkdatabase>
          <database>training</database>
          <district>AB</district>
          <add_name>Aberdeenshire</add_name>
     </linkdatabase>

     <imag_src >Aberdeenshire.gif</imag_src>

     <areas>

       <area>
          <shape type="poly" />
          <coords>580,315,545,315,493,319,495,290,573,291,580,315</coords>
          <sub_map name="Turrif"> ./turrif/turrif.htm</sub_map>
       </area>

       <area>
          <shape type="poly" />
          <coords>517,196,459,190,456,229,471,251,507,250,581,234,573,204
          </coords>
          <sub_map name="Aberdeen_city"> ./aberdeen_city/averdeen_city.htm
          </sub_map>
       </area>

     </areas>

</scope_map>
```

Figure 4-9 An example of the implementations of the scope map object :XML.

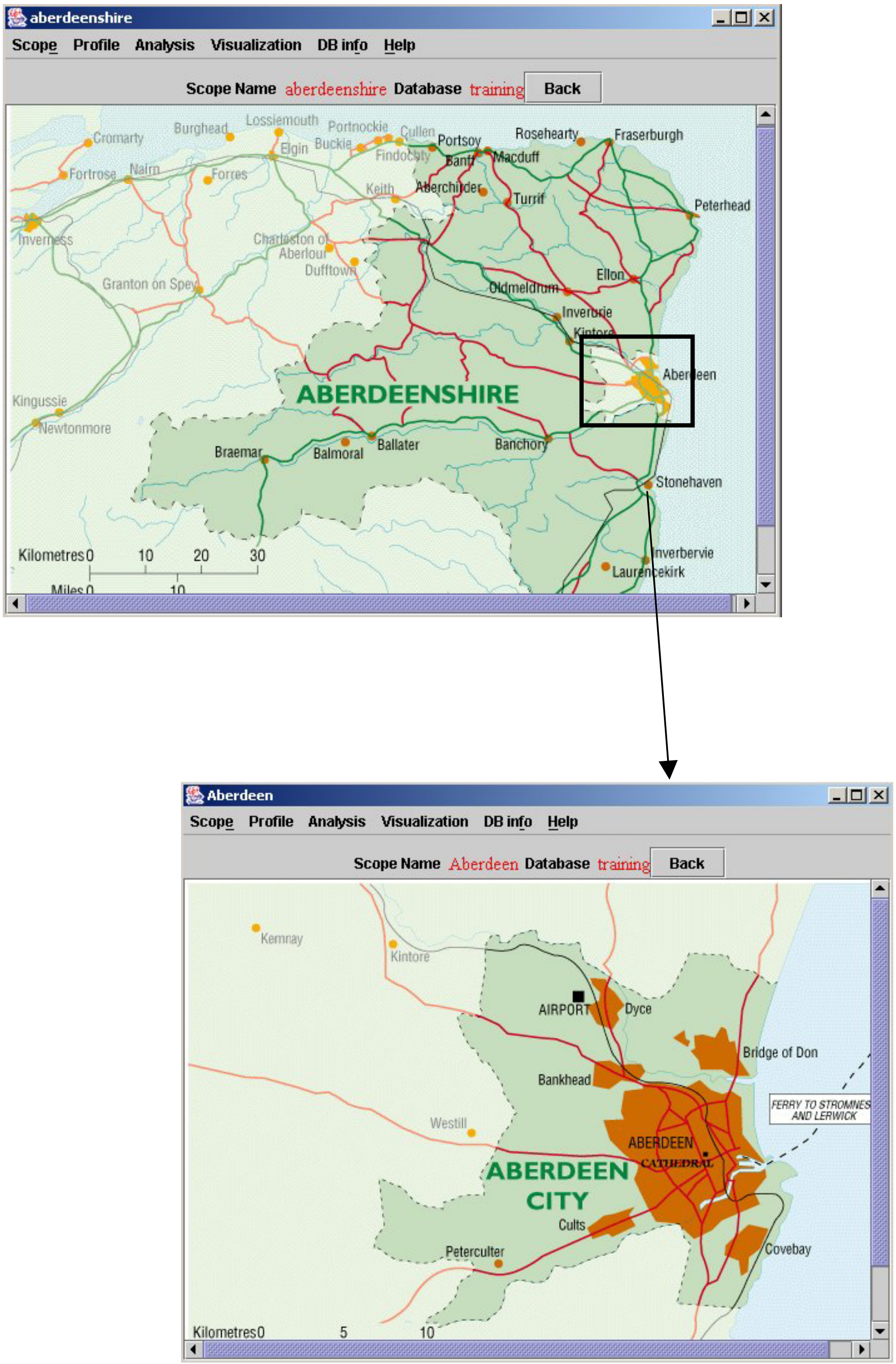


Figure 4-10 Scope map views.

4.3 Delivering Multi-View Information

As mentioned in Chapter 3, the analysis techniques required in the EEIS vary from conventional monitoring/targeting approaches to modelling and data visualisation. While the tools for the analysis create various outcomes (e.g. comparative, exploratory etc), the outcomes may have different views according to parameters such as targeting scope, period, fuel type and so on. The outcomes from different analyses are sometimes associated with each other. For example, the result of a regression analysis is used within a CUSUM analysis. Users may want to see energy profiles for a certain group of buildings annually, monthly, daily or less. The result views may be displayed in different formats (e.g. total, average etc). In order to deliver the outcomes with multiple views to different decision-makers, it is important to handle multi-scale energy environment data in a consistent and integrated way and to establish a data communication model that operates within the network environment.

Figure 4-11 illustrates the analysis process model in the EEIS. There are three functional layers: data pool, analysis tools and result views. Data or objects created by components at each layer are delivered to the next layer through communication streams so that the process may be carried out either locally or remotely. Separating the analysis process into three independent layers, and integrating them through network communication, makes the implementation of the analysis process flexible so that it is possible to make the connection between one data source and multiple analysis algorithms, and one analysis algorithm to multiple views of outcomes.

While the source of the data for all of the analysis tools is the EEIS database, each analysis tool needs its own data model. The Data Aspect Model (DAM) required by the analysis tool is a 'data view' selected from the EEIS database in a form defined by the analysis algorithm. The DAM is created and positioned in a data pooling area to be utilised by the corresponding analysis tool. Data pooling can be implemented in either a local system or a remote system on the basis of network communication. A communication stream for the data pooling is required between the EEIS database and the data pooling area. An SQL communication protocol that enables the communication stream in three tiers of the analysis process model has been implemented in the EEIS.

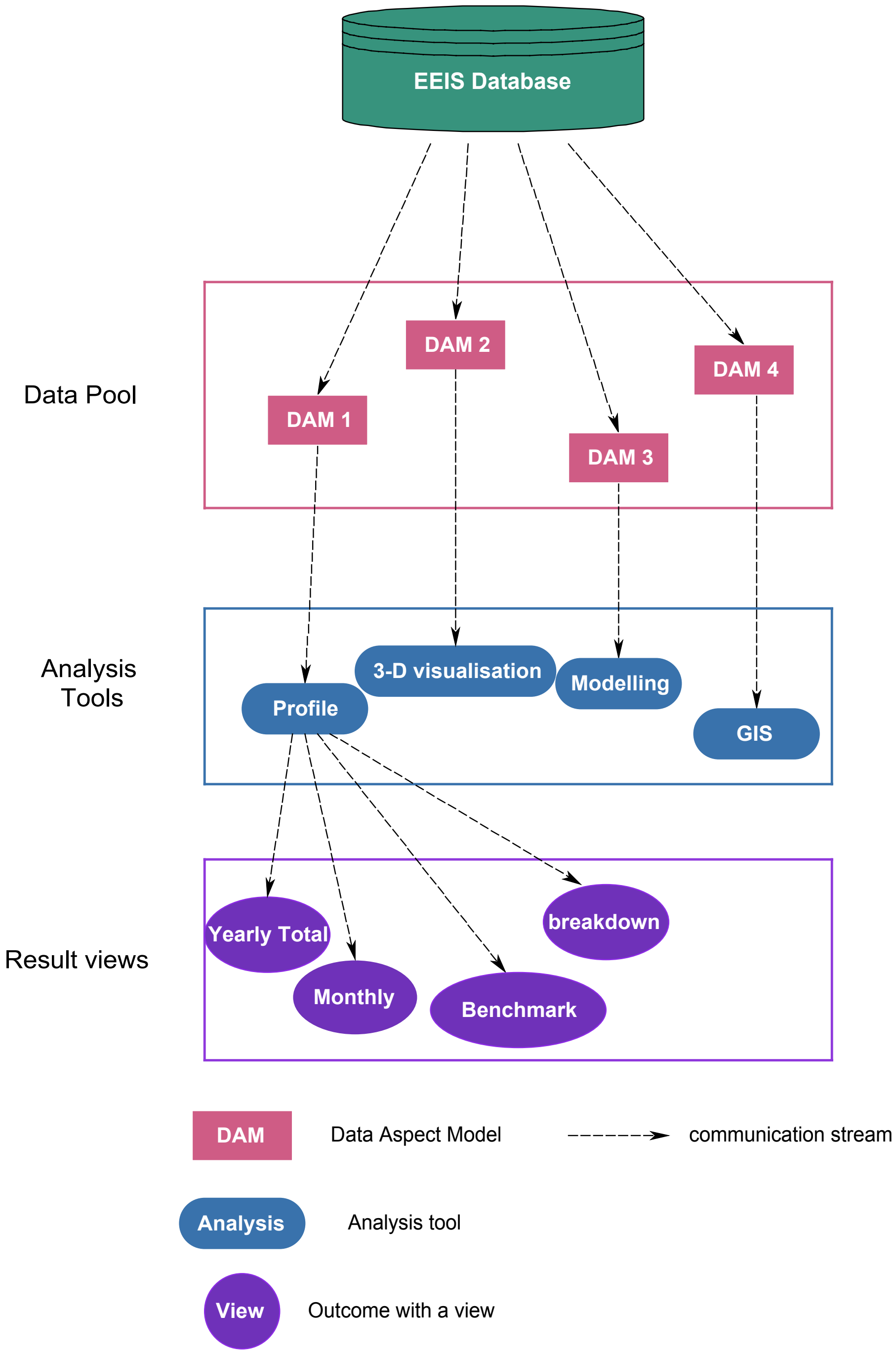


Figure 4-11 Analysis model in the EEIS.

The analysis tools possess algorithms and data input/output interfaces. They possess data input, calculating process and result output. The analysis tools located over the network receive the DAMs from the data pool layer through a communication stream. Some of the analysis tools need to create a transformed data table by sorting or merging data in the DAM to create multiple views according to different frequency, different criteria (e.g. total or average consumption) and so on. The outcomes are delivered to users through a communication stream which may be HTTP or a data socket.

The outcomes from the analysis tools are viewed using user interfaces corresponding to the result views layer. The user interfaces dealing with the outcomes provide a control panel for input parameters (e.g. targeted scopes, period, fuel type, frequency and so on) and a display facility with different formats (e.g. tables, simple charts, interactive graphic interfaces and so on). Even if the user interfaces are associated with the nature of the analysis, they do not need to be connected with the analysis tools directly. Because the outcomes can be transferred as an object from the analysis tools layer to the result view layer, the user interfaces can create various views with the object as long as the content of the outcomes is available.

Some examples of DAMs and user interfaces regarding analysis techniques such as energy profiling, regression analysis, property classification and gas emissions mapping are presented in the following sub-sections.

Energy Consumption Profiles

The energy consumption of a scope can be viewed in various ways as illustrated in Figure 4-12. Yearly, monthly and daily energy totals may, for example, be shown in a bar chart merging the data of the DAM. More detailed profiles such as daily or hourly profiles may be displayed in line graphs. The data of the DAM has to be sorted or calculated for the individual profiles. Energy breakdowns and classifications may be displayed via pie charts for which the data of the DAM needs to be resorted. The

ref_ref	add_name	to_date	tot
162571	Aboyne	1991-01-31	1476.0
162571	Aboyne	1991-01-31	4807.0
162572	Aboyne	1991-01-31	190.0
162572	Aboyne	1991-01-31	1805.0
162581	Alford	1991-01-31	4702.0
162581	Alford	1991-01-31	3825.0
162631	Ellon	1991-01-31	1899.0
202511	Aberdeen 3	1991-01-31	5400.0
202511	Aberdeen 3	1991-01-31	3890.0
212011	Aberdeen 2	1991-01-31	27002.0
212011	Aberdeen 2	1991-01-31	100290.0
162512	Aberdeen 1	1991-02-01	6566.0
162532	Buckie	1991-03-02	636.0
162552	Banff	1991-03-02	768.0
162572	Aboyne	1991-03-02	190.0
202511	Aberdeen 3	1991-03-03	4860.0
202511	Aberdeen 3	1991-03-03	3630.0
212011	Aberdeen 2	1991-03-03	12921.0
202511	Aberdeen 3	1991-03-31	5050.0
162511	Aberdeen 1	1991-04-01	150.0
162532	Buckie	1991-04-01	636.0
162552	Banff	1991-04-01	768.0
162572	Aboyne	1991-04-01	190.0
202511	Aberdeen 3	1991-04-01	3810.0

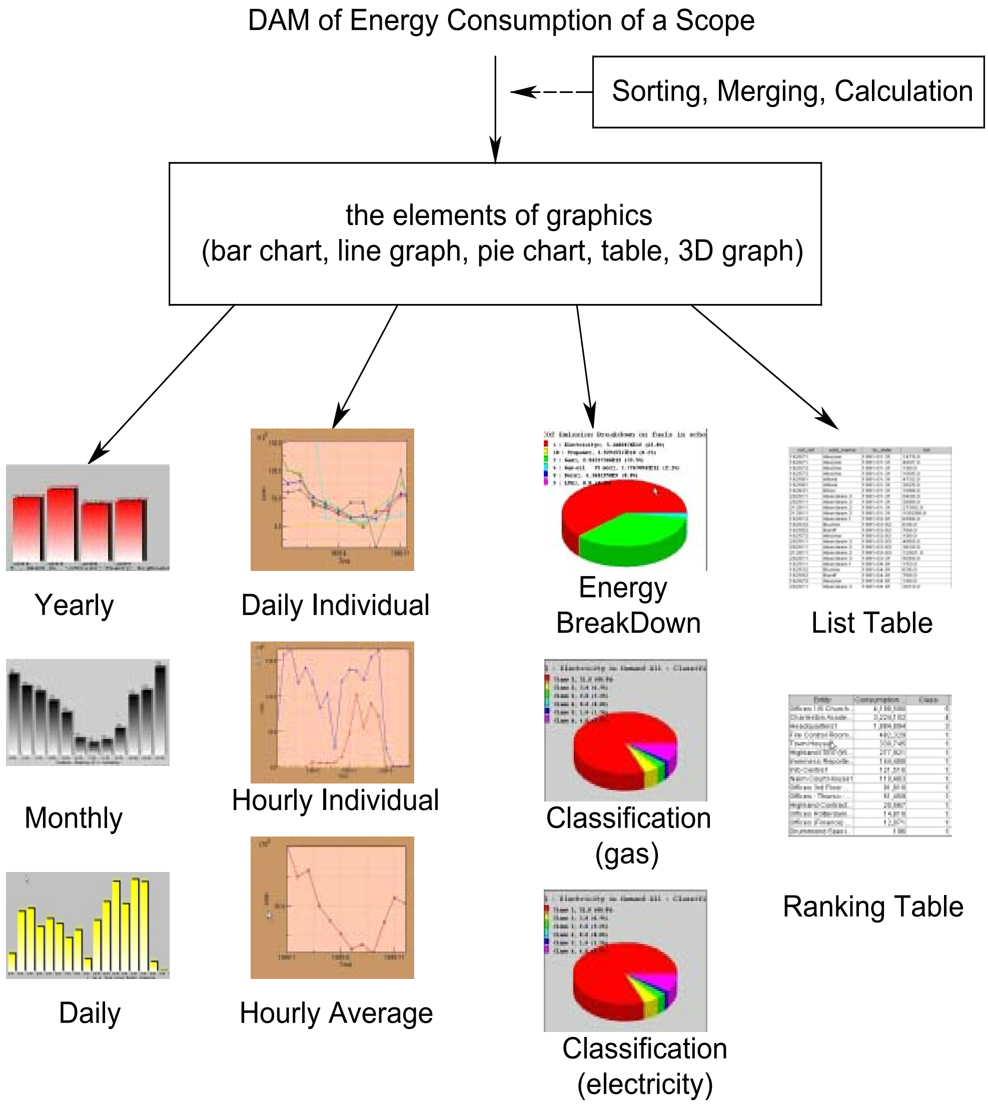


Figure 4-12 Multiple-views regarding the energy consumption based on a DAM.

energy ranking of buildings in the scope is displayed in a table. In this way, users can explore the outcomes from various viewpoints in an integrated manner.

The DAM is implemented in a Data Aspect Table (DAT) by using SQL statements (see Table 4-17). The scope condition statement is implemented by referring to the scope model. The DAT sometimes needs to be transformed into a different format. Once the DAT is taken from the EEIS database (see Figure 4-13), it is transformed to another format to suit the methods in an analysis tool (Figure 4-14). On the basis of the transformed data model, the methods of the analysis tool merge or sort DAT to create their own outcomes. The outcomes are then delivered to users with different media (e.g. interactive spreadsheet style tables, zoom-enabled graphs, and auto-scalable charts).

Table 4-17 SQL statement for the DAT for energy consumption profile.

SQL statement
SELECT energy.ref, entity.name, energy.to_datetime, energy.tot FROM database.energy LEFT JOIN database.entity ON database.energy.ref = database.entity.ref WHERE energy_condition_statement AND cope_condition_statement ORDER BY to_date, energy.ref ;
Example: SELECT energy.ref, entity.name, energy.to_datetime, energy.tot FROM training.energy LEFT JOIN training.building ON training.energy.ref = training.entity.ref WHERE (to_datetime >= '1991-01-1') AND (to_datetime <= '1992-01-16') AND energy_type= '1' AND (entity.ref like '%') AND (origin_data='DR') AND (district='AB') ORDER BY to_date, energy.ref;

ref	name	to_date	tot
162571	Aboyne	1991-01-31	1476.0
162571	Aboyne	1991-01-31	4807.0
162572	Aboyne	1991-01-31	190.0
162572	Aboyne	1991-01-31	1805.0
162581	Alford	1991-01-31	4702.0
162581	Alford	1991-01-31	3825.0
162631	Ellon	1991-01-31	1899.0
202511	Aberdeen 3	1991-01-31	5400.0
202511	Aberdeen 3	1991-01-31	3890.0
212011	Aberdeen 2	1991-01-31	27002.0
212011	Aberdeen 2	1991-01-31	100290.0
162512	Aberdeen 1	1991-02-01	6566.0
162532	Buckie	1991-03-02	636.0
162552	Banff	1991-03-02	768.0
162572	Aboyne	1991-03-02	190.0
202511	Aberdeen 3	1991-03-03	4860.0
202511	Aberdeen 3	1991-03-03	3630.0
212011	Aberdeen 2	1991-03-03	12921.0
202511	Aberdeen 3	1991-03-31	5050.0
162511	Aberdeen 1	1991-04-01	150.0
162532	Buckie	1991-04-01	636.0
162552	Banff	1991-04-01	768.0
162572	Aboyne	1991-04-01	190.0
202511	Aberdeen 3	1991-04-01	3810.0

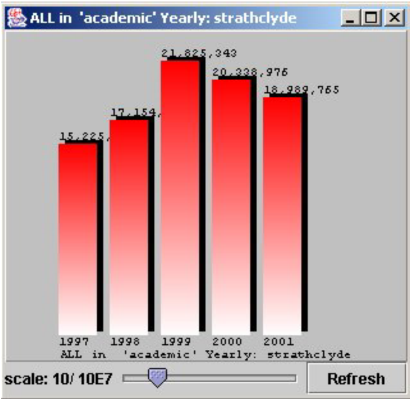
Figure 4-13 An example of the original data aspect table for energy consumption profile.

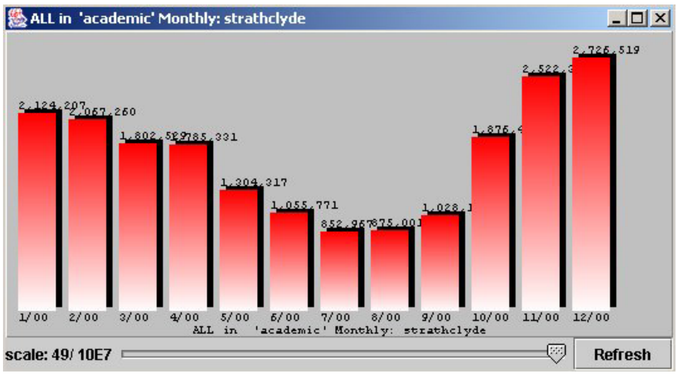
	1991-1	1991-2	1991-3	1991-4	1991-5	1991-6
Aberdeen 1(1)	100	0	150	33,987	150	150
Aberdeen 1(2)	6,566	0	0	6,503	0	0
Aberdeen 2(1)	127,292	12,921	27,002	24,962	27,002	12,921
Aberdeen 3(1)	9,290	8,490	8,860	2,790	2,720	3,450
Aboyne(1)	6,283	0	0	2,516	0	0
Aboyne(2)	1,995	190	190	692	190	190
Alford(1)	8,527	0	0	6,117	0	0
Banff(1)	6,947	0	0	13,392	0	0
Banff(2)	5,199	768	768	3,892	768	768
Buckie(1)	14,284	0	0	4,594	0	1,046
Buckie(2)	7,263	636	636	3,397	636	636
Ellon(1)	1,899	0	0	1,703	0	0
Stonehaven(1)	6,272	0	0	5,494	0	302

Figure 4-14 The transformed data aspect table for an energy use profile viewer.

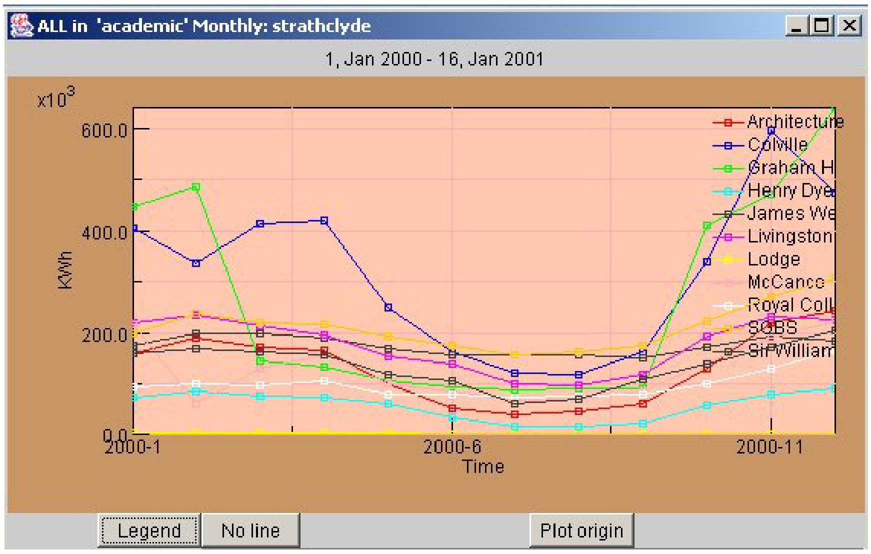
Figure 4-15 shows examples of the outcomes made by the Energy Profile Manager in the EnTrak system, which is described in Chapter 6. The tool has re-sizable and re-scalable functions to handle multi-scale energy consumption in a consistent manner.

For example, the bar chart has a scaling bar for the bar size, which allows the user to compare a bar chart with other charts corresponding to different scales. The line plot chart has an interactive user interface for resizing the chart so that users can zoom in on an area or period. In a single chart view, users can scan the multi-scale energy patterns from yearly (or more) to hourly (or less) if the data set is available.





Yearly energy consumption profile. Monthly profile.



Individual entity profiles.

Figure 4-15 Energy consumption profile displayed in different formats.

Regression and CUSUM

An example of a DAM for a regression analysis is the combination of energy and degree-days data. The regression analysis is made with two different points of view: overall performance assessment and individual benchmarking. While the target of the overall performance assessment is a scope; that of the individual benchmark is an individual building belonging to the scope. In terms of the overall performance assessment, the regression is based on the total energy consumption versus degree-days. On the other hand, regression of each building's energy consumption versus degree-days is carried out for the individual benchmark. Table 4-18 illustrates the SQL statement for the regression and CUSUM analysis.

The outcome of the regression for a scope is shown in Figure 4-17 and Figure 4-18. Figure 4-19 shows a table of individual regression-based energy performance data sorted by a correlation coefficient. The degree of scatter of the data points in the graph gives an indication of the extent to which the energy use in a building is determined by weather factors.

Table 4-18 SQL statement for the DAT for regression.

SQL statemet

```
SELECT entity.name,  energy.to_datetime, energy.tot, deg_days.dd FROM energy,
    deg_days WHERE energy.ref=entity.ref AND(year(energy.to_datetime)
    =year(deg_days.date)) AND (month(energy.to_datetime)=month(deg_days.date)) AND
    scope_condition_statement AND deg_days_condition_statement AND
    energy_fuel_condition_staement AND period_condition_statement GROUP BY
    energy.ref, year(energy.to_datetime), month(energy.to_datetime);
```

Example:

```
SELECT entity.name, energy.to_datetime, energy.tot, deg_days.dd FROMentity, energy,
    eg_days WHERE entity.ref=energy.ref, (year(energy.to_datetime) =
    year(deg_days.date)) and (month(energy.to_datetime)=month(deg_days.date)) and
    (entity.entity_type ='14' or entity.entity_type='15' or entity.entity_type='16') and
    deg_days.dd_code='WS' and energy.fuel_type='2' and deg_days.date >'1995-01-01'
    and deg_days.date <'1996-01-01' group by energy.ref, year(energy.to_datetime),
    month(energy.to_datetime);
```

name	to_date	tot	dd
Offices at Dingwall Library	1995-12-14	3156.00	465
Dochfour Drive Offices	1995-02-27	523.00	304
Dochfour Drive Offices	1995-03-29	525.00	350
Dochfour Drive Offices	1995-04-01	254037.00	218
Dochfour Drive Offices	1995-05-01	170809.00	164
Dochfour Drive Offices	1995-06-01	128393.00	86
Dochfour Drive Offices	1995-07-01	71135.00	39
Dochfour Drive Offices	1995-08-28	99.00	38
Dochfour Drive Offices	1995-09-26	555.00	103
Dochfour Drive Offices	1995-10-01	77281.00	124
Dochfour Drive Offices	1995-11-27	628.00	246
Dochfour Drive Offices	1995-12-01	188154.00	465
Headquarters	1995-02-01	10219.00	304
Headquarters	1995-03-01	10747.00	350
Headquarters	1995-04-03	14538.00	218
Headquarters	1995-05-02	8901.00	164
Headquarters	1995-06-01	2736.00	86
Headquarters	1995-07-03	37548.00	39
Headquarters	1995-08-01	99.00	38
Headquarters	1995-09-01	1780.00	103

Figure 4-16 An example of the data aspect table for energy-degree-days regression.

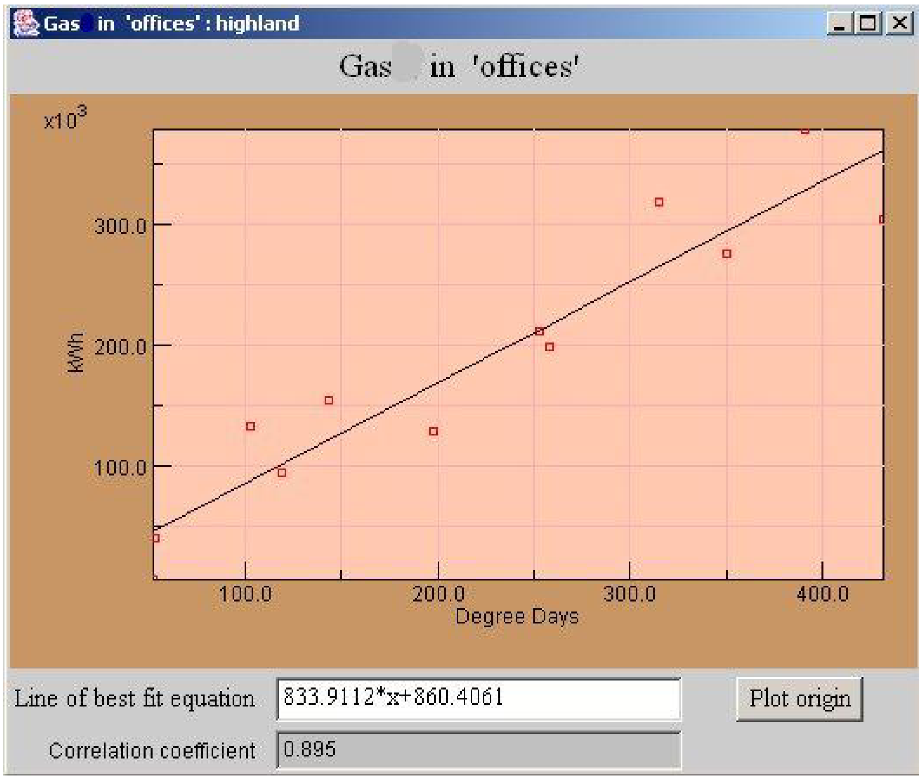
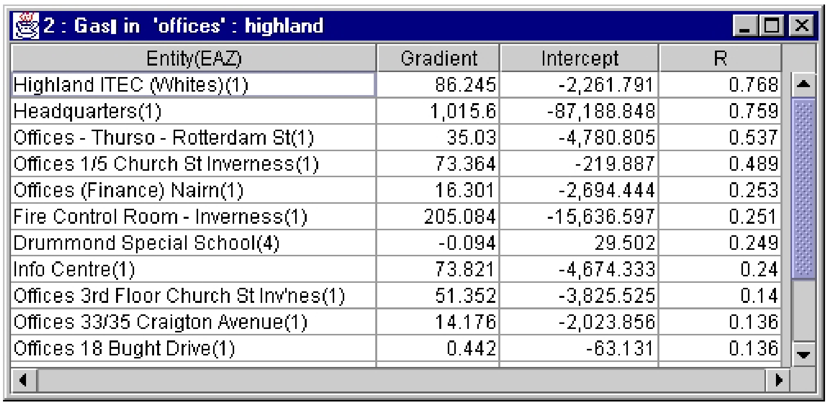


Figure 4-17 A regression graph based on overall energy consumption in a Java applet.

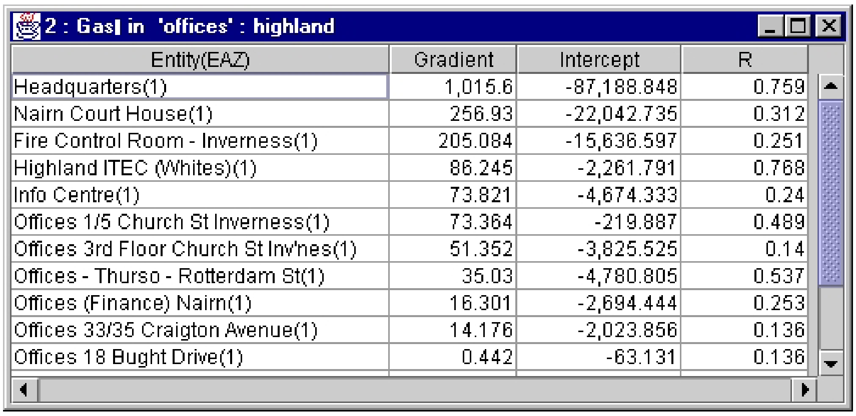
Since the correlation coefficient indicates the control efficiency, the sorted list can show which building is the poorest in terms of control. Figure 4-20 shows the table sorted by 'gradient', which implies the thermal performance of each building in terms of construction behaviour (e.g. insulation). The DAT for a CUSUM analysis is the same as the regression DAT. The CUSUM analysis manager in EnTrak implements the CUSUM analysis.



2 : Gas in 'offices' : highland

Entity(EAZ)	Gradient	Intercept	R
Highland ITEC (Whites)(1)	86.245	-2,261.791	0.768
Headquarters(1)	1,015.6	-87,188.848	0.759
Offices - Thurso - Rotterdam St(1)	35.03	-4,780.805	0.537
Offices 1/5 Church St Inverness(1)	73.364	-219.887	0.489
Offices (Finance) Nairn(1)	16.301	-2,694.444	0.253
Fire Control Room - Inverness(1)	205.084	-15,636.597	0.251
Drummond Special School(4)	-0.094	29.502	0.249
Info Centre(1)	73.821	-4,674.333	0.24
Offices 3rd Floor Church St Inv'nes(1)	51.352	-3,825.525	0.14
Offices 33/35 Craigton Avenue(1)	14.176	-2,023.856	0.136
Offices 18 Bught Drive(1)	0.442	-63.131	0.136

Figure 4-18 A regression result for individual buildings sorted by correlation coefficient ('R').



2 : Gas in 'offices' : highland

Entity(EAZ)	Gradient	Intercept	R
Headquarters(1)	1,015.6	-87,188.848	0.759
Nairn Court House(1)	256.93	-22,042.735	0.312
Fire Control Room - Inverness(1)	205.084	-15,636.597	0.251
Highland ITEC (Whites)(1)	86.245	-2,261.791	0.768
Info Centre(1)	73.821	-4,674.333	0.24
Offices 1/5 Church St Inverness(1)	73.364	-219.887	0.489
Offices 3rd Floor Church St Inv'nes(1)	51.352	-3,825.525	0.14
Offices - Thurso - Rotterdam St(1)	35.03	-4,780.805	0.537
Offices (Finance) Nairn(1)	16.301	-2,694.444	0.253
Offices 33/35 Craigton Avenue(1)	14.176	-2,023.856	0.136
Offices 18 Bught Drive(1)	0.442	-63.131	0.136

Figure 4-19 A regression result for individual buildings sorted by 'gradient' value.

Classification

The DAT for the classification is implemented by using the SQL statement shown in Table 4-19. The result of the classification is displayed graphically in a breakdown pie chart, a ranking table and a statistic bar chart (see Figure 4-20). The entities in each scope can also be inspected through a spreadsheet table.

Table 4-19 SQL Statement for the DAT for energy classification.

SQL statement
SELECT entity.name, sum(tot) FROM energy, entity LEFT JOIN entity ON energy.ref= entity.ref WHERE energy_condition_statement AND scope_condition_statement GROUP BY energy.ref_ref ;
Example: SELECT entity.name, sum(tot) FROM energy LEFT JOIN entity ON energy.ref=entity.ref WHERE (to_datetime >= '1992-01-1') AND (to_datetime <= '1993-01-16') AND energy_type = '1' AND (entity.ref like '%') AND(building.origin_data ='DR') GROUP BY entity.name;

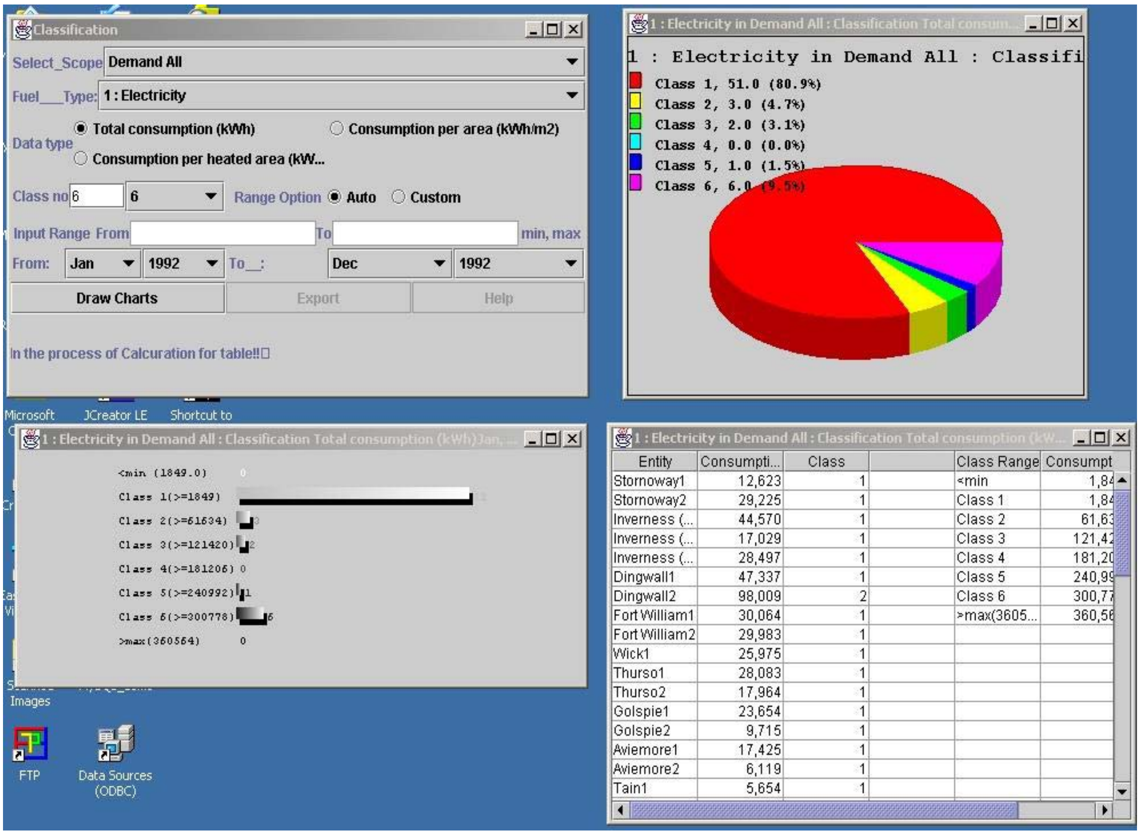


Figure 4-20 A classification result.

Gaseous Emission

The DAT for gaseous emission is implemented by using the SQL statement shown in Tables 4-20 and Table 4-21. Figure 4-21 shows the presentation of the calculation results.

Table 4-20 SQL statement for the DAT for gas emission: gas emission factor part.

SQL statement
SELECT energy_type, gas_type, factor FROM database.gas_emission_factors WHERE condition_statement ORDER BY energy_type
Example: SELECT energy_type, gas_type, factor FROM training.gas_emission_factors WHERE region_code = 'UK' AND gas_emission_code='R' AND date <='1 ORDER BY energy_type

Table 4-21 SQL statement for the DAT for gas emission: energy data part.

SQL statement
SELECT fuel_type, sum(tot), FROM database.energy LEFT JOIN database.building ON database WHERE energy_condition_statement AND scope_condition_statement ORDER BY fuel_type;
Example: SELECT fuel_type, sum(tot) FROM energy LEFT JOIN entity ON energy.ref=entity.ref WHERE (to_datetime >= '1993-01-1') and (to_datetime <= '1996-01-16') and fuel_type like '%' and entity.ref like '%') and(entity.origin_data ='DR') group by energy_type ORDER BY fuel_type;

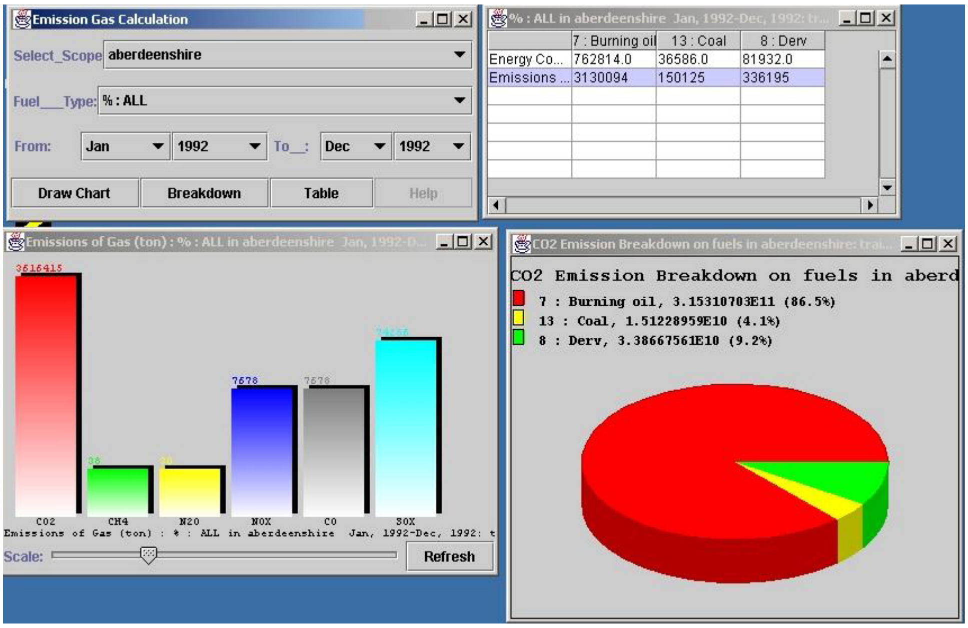


Figure 4-21 A gaseous emissions analysis

4.4 Exploratory Analysis Model via 3D Data Visualisation

As discussed previously, the 3D data visualisation is expected to offer a new approach to exploratory analysis within the EEIS. A 3D data visualisation model has been developed on the basis of Benedikt's data spaces model:

- to identify the energy pattern within a scope of entities, which are clustered into several sub-groups according to entity types;
- to discover the problematic entities in each group as entities drifting away from the predominant pattern; and
- To perceive the energy patterns of each group and diagnose questionable phenomena.

The feasibility of a decision-support tool is concerned with whether the tool produces informative outcomes that have value to the decision-maker. To this end, a case study using field data collected from a utility company was undertaken to verify the applicability of the 3D visualisation model. Some practical issues in defining a such a model are discussed in the following sub-sections.

4.4.1 Configuration of Data Spaces Model

A data aspect model was firstly defined for the 3D visualisation model. This consists of a scope of entities (i.e. ID, name, type, heating volume) and energy use data corresponding to each entity. Secondly, the dimensions of the 3D visualisation model were defined including spatial dimensions and attribute dimensions. The spatial dimensions are associated with the x,y,z axis of the 3D graph, which defines a virtual space. The attribute dimensions are related to the characteristics (i.e. shapes, colours and rotations) of the objects to be plotted in the space.

In this study, in order to define a trial assessment model on energy use performance, spatial dimensions are assigned to energy use, heating volume and normalised energy use (i.e. energy use per heated volume or area) because these three data items are representative data for the assessment of energy performance and commonly available. Also these data are quantitative so that they can be compared numerically. Attribute dimensions are assigned to clustering data such as entity type. As illustrated in Figure 4-22, the co-ordinate system established by total energy consumption, entity size and unit energy consumption gives rise to data spaces that reflect the energy performance of the entities.

It is supposed that the entities in a group plotted in the ‘low demand’ area are better than those plotted in the ‘high demand’ area, at least in terms of energy performance. Strategically, it may be desirable to move entities from the ‘high demand’ area to the ‘low demand’ area.

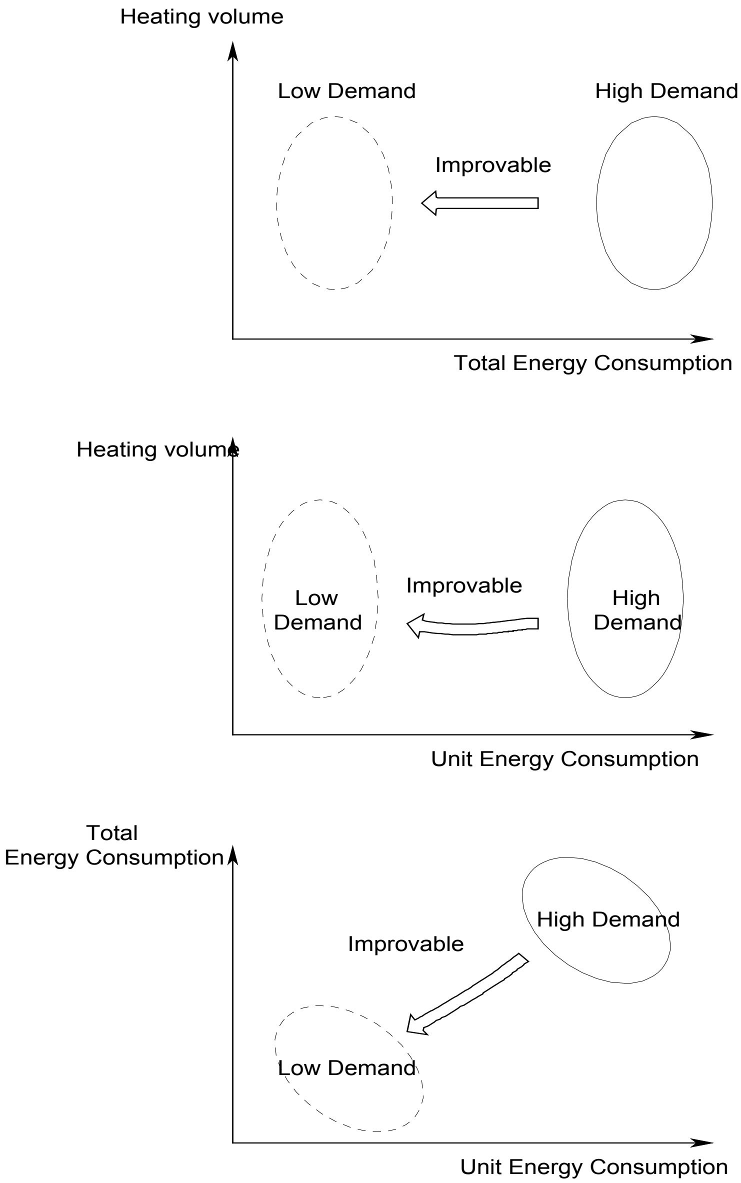


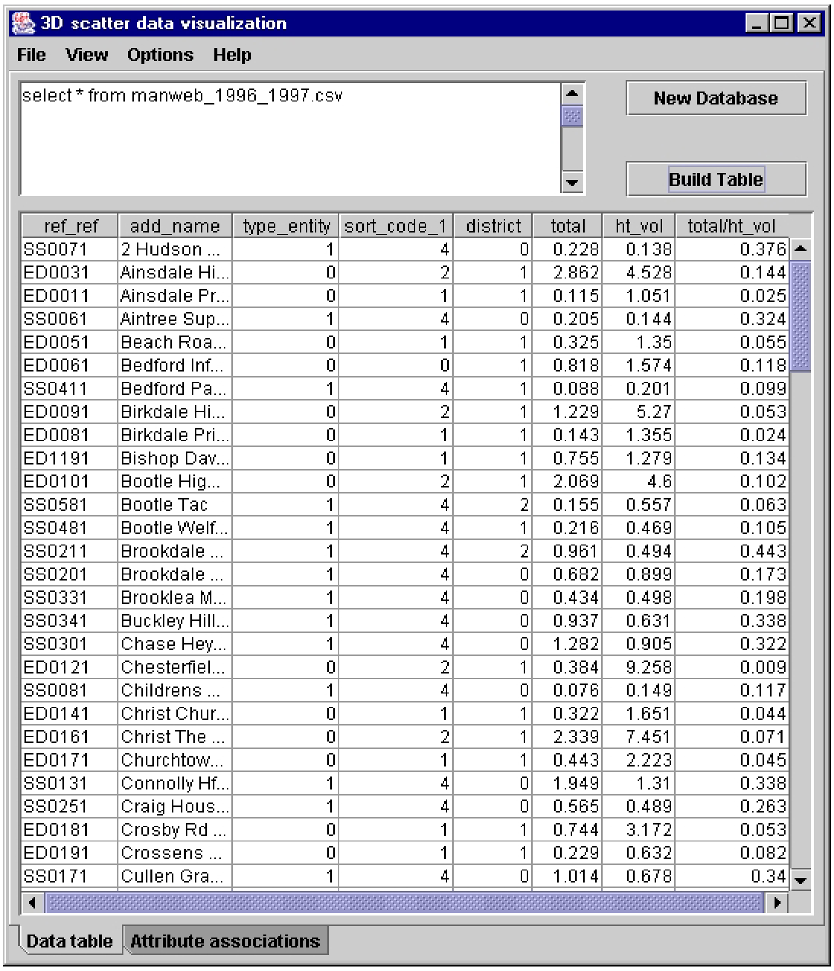
Figure 4-22 Data spaces identifying energy pattern and performance of entities.

4.4.2 Development of a 3D Visualisation Tool

A 3D visualisation tool was developed using Java APIs. The 3DScatterGraph API package is based on the Java 3D package (com.sun.3d, javax.media.j3d, javax.vecmath) (Sun Microsystems 2002, Bouvier 1999). The Java class plots data in the 3D space with colour and shape. The software tool consists of three parts as follow.

Data Aspect Table (DAT) connection

This is required to connect to data sources that contain the data aspect model for data visualisation. The data aspect model from the EEIS database is physically implemented in a DAT. The DAT can be a data source of open database connectivity. Figure 4.23 shows the appearance of the user interface.



ref_ref	add_name	type_entity	sort_code_1	district	total	ht_vol	total/ht_vol
SS0071	2 Hudson ...	1	4	0	0.228	0.138	0.376
ED0031	Ainsdale Hi...	0	2	1	2.862	4.528	0.144
ED0011	Ainsdale Pr...	0	1	1	0.115	1.051	0.025
SS0061	Aintree Sup...	1	4	0	0.205	0.144	0.324
ED0051	Beach Roa...	0	1	1	0.325	1.35	0.055
ED0061	Bedford Inf...	0	0	1	0.818	1.574	0.118
SS0411	Bedford Pa...	1	4	1	0.088	0.201	0.099
ED0091	Birkdale Hi...	0	2	1	1.229	5.27	0.053
ED0081	Birkdale Pri...	0	1	1	0.143	1.355	0.024
ED1191	Bishop Dav...	0	1	1	0.755	1.279	0.134
ED0101	Bootle Hig...	0	2	1	2.069	4.6	0.102
SS0581	Bootle Tac	1	4	2	0.155	0.557	0.063
SS0481	Bootle Welf...	1	4	1	0.216	0.469	0.105
SS0211	Brookdale ...	1	4	2	0.961	0.494	0.443
SS0201	Brookdale ...	1	4	0	0.682	0.899	0.173
SS0331	Brooklea M...	1	4	0	0.434	0.498	0.198
SS0341	Buckley Hill...	1	4	0	0.937	0.631	0.338
SS0301	Chase Hey...	1	4	0	1.282	0.905	0.322
ED0121	Chesterfiel...	0	2	1	0.384	9.258	0.009
SS0081	Childrens ...	1	4	0	0.076	0.149	0.117
ED0141	Christ Chur...	0	1	1	0.322	1.651	0.044
ED0161	Christ The ...	0	2	1	2.339	7.451	0.071
ED0171	Churchtow...	0	1	1	0.443	2.223	0.045
SS0131	Connolly Hf...	1	4	0	1.949	1.31	0.338
SS0251	Craig Hous...	1	4	0	0.565	0.489	0.263
ED0181	Crosby Rd ...	0	1	1	0.744	3.172	0.053
ED0191	Crossens ...	0	1	1	0.229	0.632	0.082
SS0171	Cullen Gra...	1	4	0	1.014	0.678	0.34

Figure 4-23 Selected data view in table.

The URL of the data source is entered in the initial dialog box. The database URL is configured according to the type of data connectivity (e.g. 'JDBC:ODBC:Data Source Name' for ODBC or 'JDBC:mysql:/host_name/database' for mysql database). The driver is for JDBC, which also depends on the type of data connectivity. Once the DAT has been connected, the next dialog box appears where users can make a data query using SQL commands. If the query commands are valid, the data selected from the DAT is displayed in a box below the command input box.

Configuring Attribution

The data fields of the data table (Figure 4-24) are assigned to dimensional attributes.

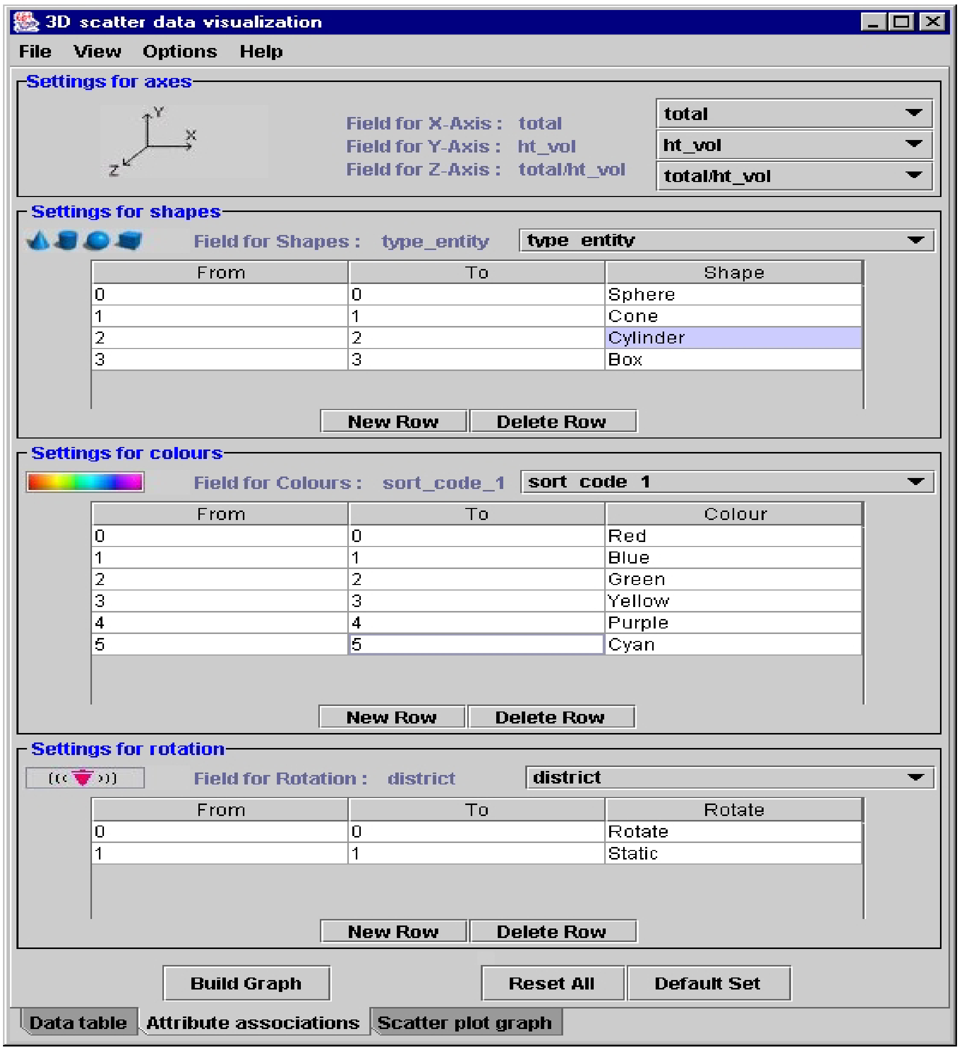


Figure 4-24 Spatial dimensions and object attribution setting.

There are 3 axes that define the dimensions of some virtual space and 3 kinds of object attributes: shape, colour and rotation. There are 4 options available in the shape attribute (sphere, cone, cylinder and box). The colour of an object in the virtual space can be assigned. The colour attribute has 6 options (red, blue, green, yellow, purple and cyan). The rotation attribute has 2 options (rotate or static). To obtain perceptive views, it is necessary to find proper levels of the attribute setting.

Result view

Once setting attributes have been completed, the result view is displayed. Different views can be shown via interactive mouse operations. The graph's angle can be rotated and the image scaled and translated interactively. Figure 4-25 shows an outcome created from the tool.

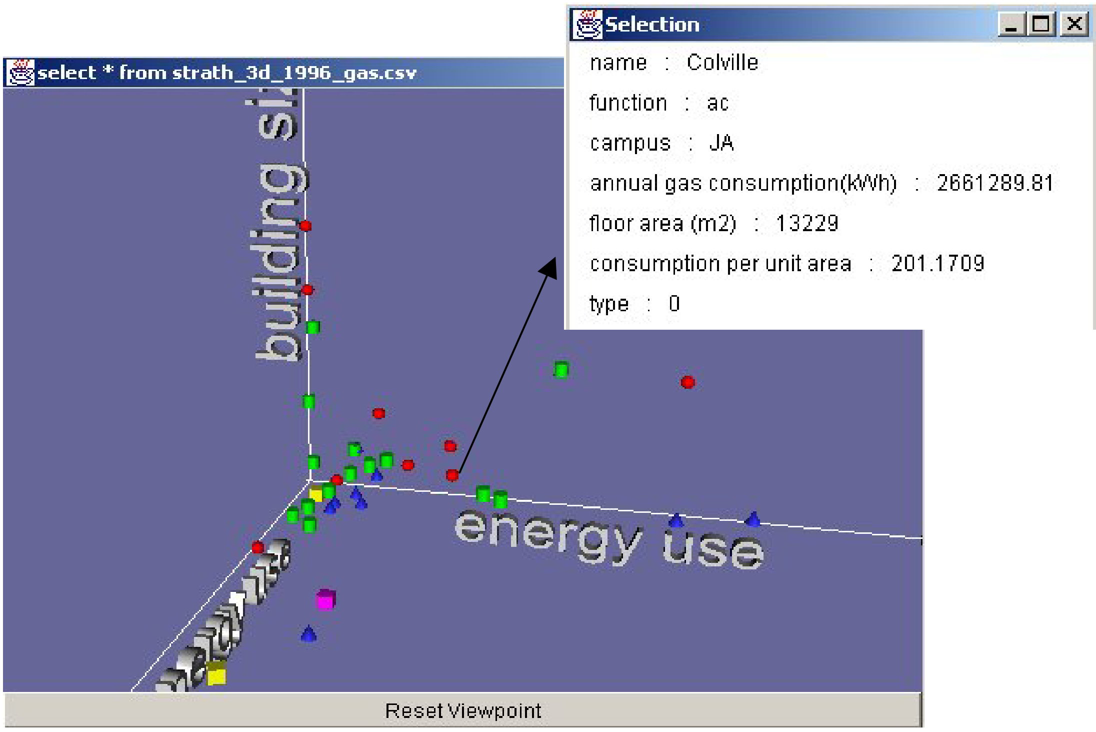


Figure 4-25 Result view: zoom in/out mode.

The entities plotted in the 3D view are mouse-sensitive. By clicking an object representing an entity in the data space, the information about that entity is displayed in a separate pop-up window. This feature makes it straightforward for users to 'drill-down' an entity.

4.4.3 Practical Issues

To create perceptive views in the 3D visualisation tool, there are some practical issues. The DAT to be taken from the EEIS database may depend on the data validity and availability because data in some fields may be missing or have invalid values. The DAT can be stored in an ODBC data source, which is a data pooling area (i.e. one of the tiers in the analysis process model described in 4.3 Section). Several DATs may be defined by users according to their particular analysis needs. Selecting data fields to make a DAT is crucial to the creation of an efficient graphic index in which the pattern or characteristics are shown clearly.

However, not every data field is suitable for data visualisation because the data format, range and scale are variable. Therefore, the data of the original DAT needs to be tuned through the process of cleaning, coding and re-scaling. According to the condition of the analysis, some data may need to be removed from the DAT if errors are present. Further, data items in character format have to be transferred to numeric codes. Numeric data fields assigned to special dimension (i.e. to x, y and z axes) need to be re-scaled properly. Otherwise, data may not be shown in the 3D data space. The scale adjustment of numeric data fields is likely to affect the visual impression, which is sometimes crucial when used to identify the data patterns.

The outcomes shown in Figure 4-26 and Figure 4-27 are examples of how the different scales affect the perception of the plotted data. The view of Figure 4-26 is created by adjusting data fields corresponding to x, y and z axes to max_x: max_y: max_z = 10:10:10 scale ratio. Here, 'max_x' means the maximum value of data field assigned to the x axis.

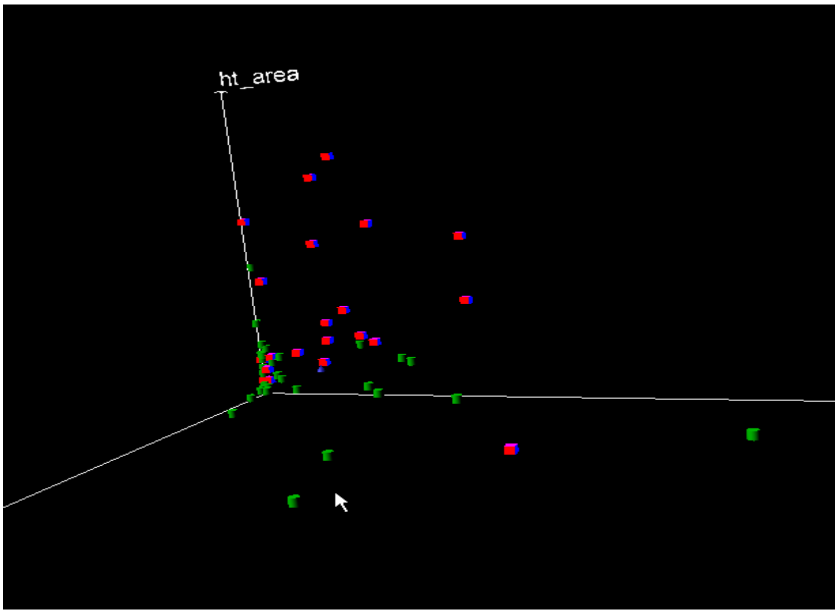


Figure 4-26 outcome of the re-scaled data (10:10:10).

In Figure 4-27, the scale is 100:10:100. Although both outcomes come from the same DAT, the view is different. The pattern created by the green dots in the scale of 10:10:10 is totally different from that in the scale of 100:10:100. While it usually takes time to find an effective combination of the scale adjustment, it is crucial to make sensible outcomes.

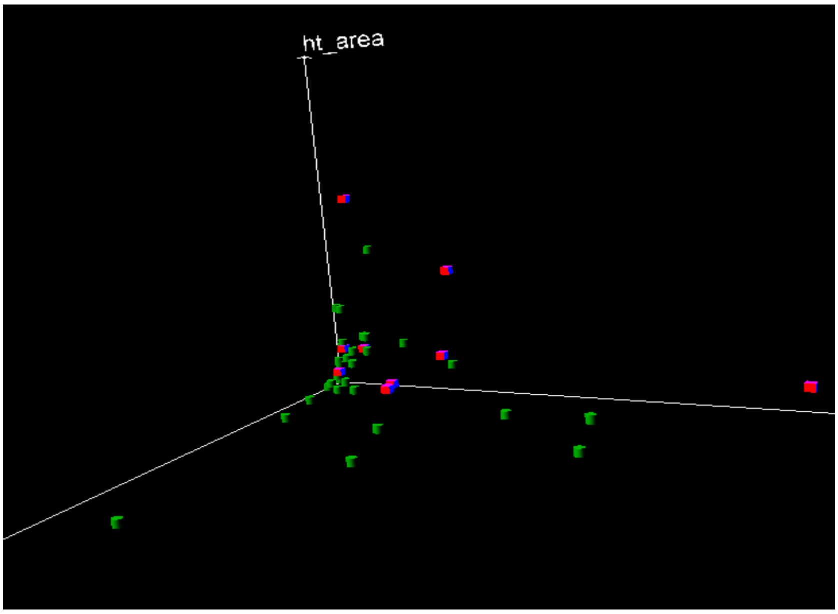


Figure 4-27 outcome of the re-scaled data (100:10:100).

The attribution mapping of data fields to the graph is also important. Each data field must be assigned to the attributes of the 3D graph (i.e. x, y and z axes and objects). As defined previously, it is generally acceptable that the data fields with graduated numeric values (e.g. energy consumption, volume, cost etc) are set to geometric dimensions, while the data fields with unique values (e.g. entity type, sort code, energy type etc) are mapped to the property of the objects (i.e. colour, shape or rotation).

Because the views by the 3D visualisation tool depends on the manipulation of the data, including data selection, data conversion and attribution mapping, the outcomes are subject to the configuration made by users. Therefore, it is important to retain the consistency of the analysis process when comparing the energy patterns of different periods or different scopes. This consistency can be achieved by using the same data model, applying the same scale ratio and mapping the same attribution. By unifying such parameters, users can define a 3D visualisation analysis model.

4.4.4 Applicability

Established Database and Data-Space Model configuration

A set of energy data was collected from a utility company and used to assess EEIS applicability. The data set covers public service buildings in the Sefton area, North West England, as illustrated in Figure 4-28.

The total number of entities in the building table is 412. Among the registered entities, there are 153 entities that have valid building information (e.g. heating volume). As described in Table 4-22, the entities are categorised into 5 types: social service, infant school, primary school, junior school and high school. The social service type involves day nurseries, elderly peoples' homes, training centres and homeless shelters. The electricity consumption for the year from May 1996 to April 1997 was used. The annual energy consumption is shown in Table 4-23.

Figure 4-28 Geographic location of the area of the sample buildings.

Table 4-22The figures of entities of the sample database.

Entity Type	*Number*
Social Service	48
Infant School	6
Primary School	73

Junior School	7
High School	19
Total	153

Table 4-23 The figures of annual energy consumption of the sample database.

	Total Consumption (kWh)	*Heating Volume (m^3)*	*Consumption per Heating Volume (kWh/m^3)*
Average	78,151	2096	54
Maximum	920,010	12313	386
Minimum	1410	75	3

To make the DAT based on the 3D visualisation analysis model, the following SQL statement has been used.

```
SELECT entity.ref,entity.name, entity_type, sort_code_1, district, SUM(tot), ht_vol, sum(tot/ht_vol) FROM
    energy LEFT JOIN entity ON energy.ref = entity.ref  WHERE  to_date > '1996-05-15' AND to_date
    <'1997-05-01' AND energy_type = '1' GROUP BY entity.ref
```

The fields of 'ref' and 'name' in the entity table corresponds to ID information. The fields of 'entity_type', 'sort_code_1' and 'district' in the building table relate to entity clustering. The field of 'sort_code_1' indicates the type of entity according to the function of the building. There are 5 groups as described in Table 4-24. The field 'type_entity' is used to sort the entities into two groups: education facility (ED) and social service (SS). The group of education facility involves schools while the group of social service is identical to social service in the field of 'sort_code_1'. The annual total energy consumption of each entity is obtained as the result of function 'SUM()' as shown in the field of 'tot' in the energy table. The field of 'ht_vol' (i.e. heating volume) in the building table is used for the entity size.

Table 4-24 Encoding data and attribution mapping.

Field	*Code*	*Description*	*Converted Numeric Value*	*Attribution*
Type_entity	ED	Education	0	Sphere
	SS	Social Service	1	Cone
Sort_code_1	IN	Infant School	0	Red
	PR	Primary School	1	Blue
	JU	Junior School	2	Yellow
	SE	Secondary School	3	Green
	SS	Social Service	4	Purple

The result of the SQL statement is shown in Figure 4-29. The DAT is stored in an ODBC data source. When making the ODBC data source, the field name of ‘sum(tot)’, ‘ht_vol’ and ‘sum(tot/ht_vol)’ are changed to ‘total’, ‘ht_vol’ and ‘total/ht_vol’ respectively. The encoding process for the fields of ‘type_entity’ and ‘sort_code_1’ has been implemented before the attribution mapping for the objects to be plotted in the 3D graph is made. The code list and the attribution mapping are given in Table 4-22.

The re-scaling of ‘total’, ‘ht_vol’ and ‘total/ht_vol was implemented on the basis of the 10:10:10 scale mapping of the xyz co-ordinates. The converted values are calculated from

total / Cfx = total’

ht_vol / Cfy = ht_vol’

total/ht_vol / Cfz = total/ht_vol’

where Cfx, Cfy and Cfz are the conversion factors, total, ht_vol and total/ht_vol are the origin values of the fields, and total’, ht_vol’ and total /ht_vol’ are the converted values of the fields. The conversion factors are obtained from the equation

Max_total / Cfx : Max_ht_vol / Cfy : Max_unit /Cfz = 10:10:10

where Max_total is the maximum value of total, Max_ht_vol is the maximum value of ht_vol and Max_unit is the maximum value of total/ht_vol. Therefore, the conversion factors for this DAT are

Cfx = 92001,

Cfy = 1231,

Cfz = 38.6.

Figure 4-29 and Figure 4-30 show the original DAT and the converted DAT respectively.

ref	_name	type_entity	sort_code_1	district	sum(tot)	ht_vol	sum(tot/ht_vol)
ED0011	Ainsdale Pri...	ED	PR	WD	12447.0	1294.0	9.619
ED0021	Ainsdale Pri...	ED	IN	WD	7345.0	0.0	0.0
ED0031	Ainsdale Hi...	ED	SE	WD	309441.0	5574.0	55.5151
ED0051	Beach Roa...	ED	PR	WD	35168.0	1662.0	21.16
ED0061	Bedford Infa...	ED	IN	WD	88454.0	1938.0	45.6419
ED0081	Birkdale Pri...	ED	PR	WD	15445.0	1668.0	9.2596
ED0091	Birkdale Hig...	ED	SE	WD	132873.0	6487.0	20.483
ED0101	Bootle High ...	ED	SE	WD	223685.0	5663.0	39.4994
ED0111	Cambridge ...	ED	NU	WD	5663.0	0.0	0.0
ED0121	Chesterfield...	ED	SE	WD	41520.0	11397.0	3.6431
ED0141	Christ Chur...	ED	PR	WD	34842.0	2032.0	17.1467
ED0161	Christ The ...	ED	SE	WD	252850.0	9172.0	27.5676
ED0171	Churchtown...	ED	PR	WD	47892.0	2736.0	17.5044
ED0181	Crosby Rd ...	ED	PR	WD	80474.0	3905.0	20.6079
ED0191	Crossens C...	ED	PR	WD	24719.0	778.0	31.7725
ED0201	Crossens N...	ED	NU	WD	5435.0	0.0	0.0
ED0211	Daleacre Pr...	ED	PR	WD	26596.0	1057.0	25.1618
ED0221	Davenhill S...	ED	PR	WD	133321.0	3988.0	33.4305
ED0231	Deyes High ...	ED	SE	WD	920010.0	9706.0	94.7878
ED0241	English Mar...	ED	PR	WD	48404.0	2800.0	17.2871
ED0251	Farnboroug...	ED	JU	WD	56028.0	2315.0	24.2022
ED0261	Farnboroug...	ED	IN	WD	26262.0	1781.0	14.7456
ED0271	Forefield La...	ED	JU	WD	41646.0	1732.0	24.045
ED0281	Forefield La...	ED	IN	WD	79909.0	1462.0	54.6573
ED0291	Formby Hig...	ED	SE	WD	680.0	8736.0	0.0778
ED0301	Freshfield P...	ED	PR	WD	24580.0	1806.0	13.6102
ED0311	School Of G...	ED	PR	WD	76098.0	0.0	0.0
ED0321	Grange Pri...	ED	PR	WD	127850.0	1568.0	81.537
ED0331	Great Crosb...	ED	PR	WD	25954.0	2333.0	11.1247
ED0341	Greenacre...	ED	NU	WD	12671.0	0.0	0.0

Figure 4-29 the DAT Taken from the EEIS database.

ref_	_name	type_entity	sort_code_1	district	total	ht_vol	total/ht_vol
ED0011	Ainsdale Pr...	0	1	1	0.115	1.051	0.249
ED0031	Ainsdale Hi...	0	2	1	2.862	4.528	1.438
ED0051	Beach Roa...	0	1	1	0.325	1.35	0.548
ED0061	Bedford Inf...	0	0	1	0.818	1.574	1.182
ED0081	Birkdale Pri...	0	1	1	0.143	1.355	0.24
ED0091	Birkdale Hi...	0	2	1	1.229	5.27	0.531
ED0101	Bootle Hig...	0	2	1	2.069	4.6	1.023
ED0121	Chesterfiel...	0	2	1	0.384	9.258	0.094
ED0141	Christ Chur...	0	1	1	0.322	1.651	0.444
ED0161	Christ The ...	0	2	1	2.339	7.451	0.714
ED0171	Churchtow...	0	1	1	0.443	2.223	0.453
ED0181	Crosby Rd ...	0	1	1	0.744	3.172	0.534
ED0191	Crossens ...	0	1	1	0.229	0.632	0.823
ED0211	Daleacre P...	0	1	1	0.246	0.859	0.652
ED0221	Davenhill S...	0	1	1	1.233	3.24	0.866
ED0231	Deyes Hig...	0	2	1	8.51	7.885	2.456
ED0241	English Ma...	0	1	1	0.448	2.275	0.448
ED0251	Farnborou...	0	3	1	0.518	1.881	0.627
ED0261	Farnborou...	0	0	1	0.243	1.447	0.382
ED0271	Forefield L...	0	3	1	0.385	1.407	0.623
ED0281	Forefield L...	0	0	1	0.739	1.188	1.416
ED0301	Freshfield ...	0	1	1	0.227	1.467	0.353
ED0321	Grange Pri...	0	1	1	1.183	1.274	2.112
ED0331	Great Cros...	0	1	1	0.24	1.895	0.288
ED0351	Greenbank...	0	2	1	1.874	5.72	0.745
ED0361	Green Park...	0	1	1	0.339	0.91	0.848
ED0371	Hatton Hill ...	0	1	1	1.354	1.769	1.741
ED0381	Hillside Hi...	0	2	1	2.115	4.761	1.011
ED0411	Holy Spirit ...	0	1	1	0.47	1.215	0.88
ED0421	Holy Rosar...	0	1	1	0.296	1.944	0.347
ED0431	Holy Trinity ...	0	1	1	0.572	0.774	1.682
ED0441	Holy Trinity ...	0	1	1	0.224	0.989	0.516
ED0451	Hudson Pri...	0	1	1	0.136	2.205	0.14
ED0471	Kew Wood...	0	1	1	0.294	0.962	0.695
ED0491	Lander Ro...	0	1	1	0.597	1.275	1.066

Figure 4-30 the DAT converted and rescaled from the original DAT

Outcomes

The distribution of properties' heating volume and total energy consumption is shown in Figure 4-31. It illustrates that educational properties such as infant schools (red), primary schools (blue) and junior schools (yellow), are rather smaller in terms of heating volume while the secondary schools (green) have larger heating volumes. It is supposed that the secondary schools possess more facilities and higher occupancy rates than the other properties. It is also shown that the heating volume and energy consumption of the group of social service is generally smaller than for educational properties. While the properties' energy scales are easily perceived the energy performance is hardly seen from this dimension aspect.

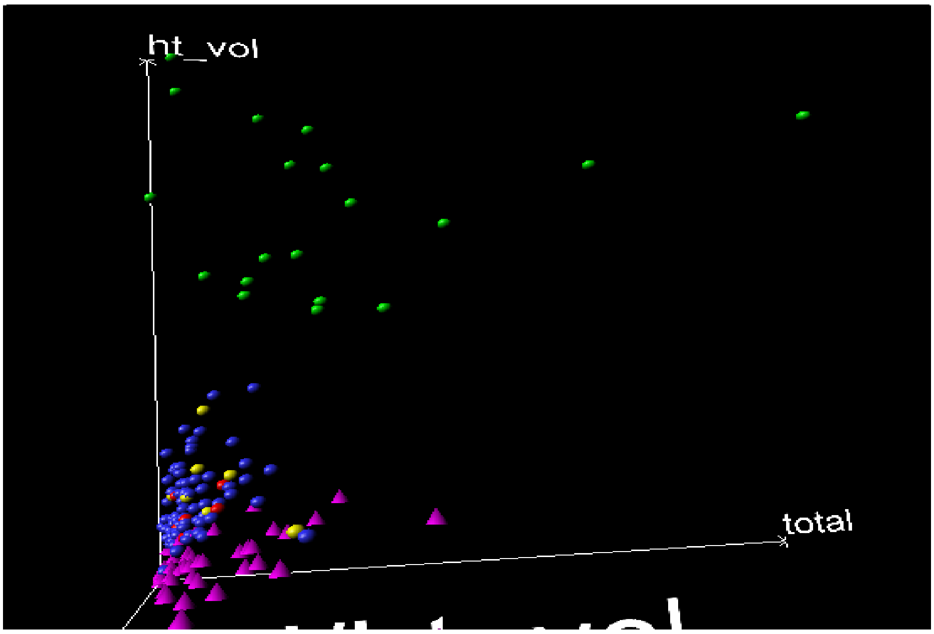


Figure 4-31 Heating volume (ht_vol) v total energy consumption (total).

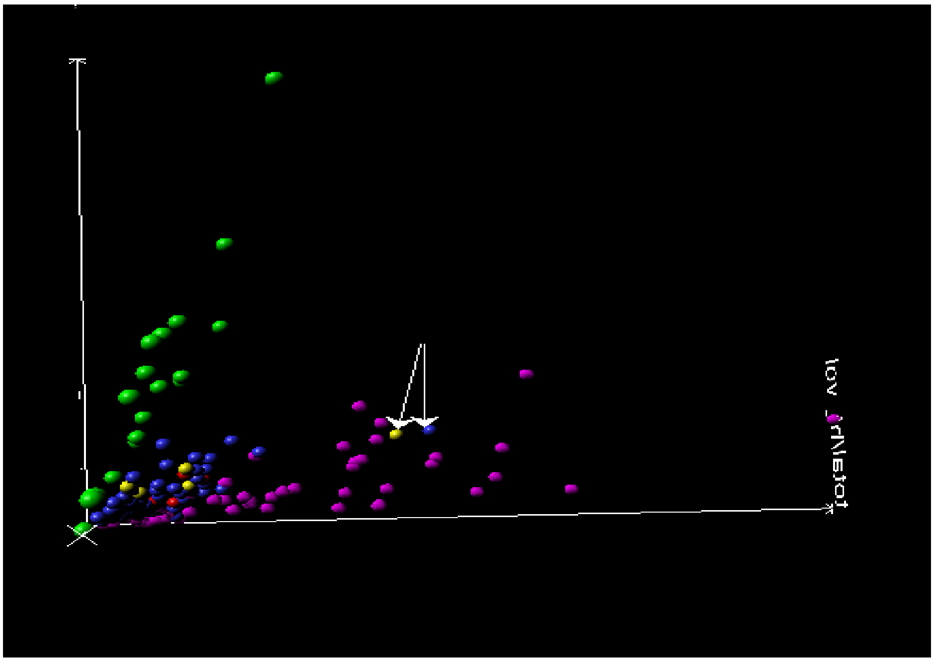


Figure 4-32 Total energy consumption ('total') v unit energy consumption ('total/ht_vol').

Meanwhile, Figure 4-32 shows an aspect of the 'total' (total energy consumption) versus 'total/ht_vol' (unit energy consumption). The data points of the secondary schools are plotted at the lower range of the ‘total/ht_vol’ axis, which implies that the energy pattern of the secondary schools shows better performance when compared to those of other groups. It indicates that although the secondary schools consumed more energy with larger heating volumes (‘ht_vol’) than other properties, the performance of energy consumption is better than that of others.

Problematic properties are noticed from this aspect. It is observed that one of primary schools and one of junior schools are apart from their respective groups (see arrows). From the location of both points, it can be judged that the energy performance of the properties is worse than other entities in the same group.

The group of social service properties (purple cone shape) has a distinctive pattern. Its data points spread alongside the axis of total/ht_vol (annual energy consumption per heating volume). It is apparent that the social service entities (purple, cone shape) have an energy pattern indicating diverse efficiencies in energy use, when compared to educational properties. The data points of the entities plotted over the whole range of the ‘total/ht_vol’ axis shows that the energy performance of the entities is variable. The reason is that a variety of entity types such as day nurseries, elderly homes, training centres and shelters are included in the group. It may be necessary to inspect the sub-groups to determine the energy demand patterns of the social service entities more concretely.

In order to improve the energy consumption patterns, strategic and tactical measures may be set up by energy managers or policy makers. Tactically, it may be appropriate to target poor performers. For example, the two problematic entities could be subjected to further investigation. Quantitative analysis such as statistical modelling (e.g. regression) would be used to identify the causes. Strategically, some energy action plan may be required in the long term base. The improvement can be easily recognised by examining the shift of the data points along the ‘total/ht_vol’ axis. For example, the data points in the circle mark (illustrated) in Figure 4-33 could be moved toward the left end of ‘total/ht_vol’ axis. It is important, though, when comparing the energy demand patterns of different scopes, that an identical data spaces model and attribution mapping (i.e. conversion factors, colours and shapes) are applied to the scopes.

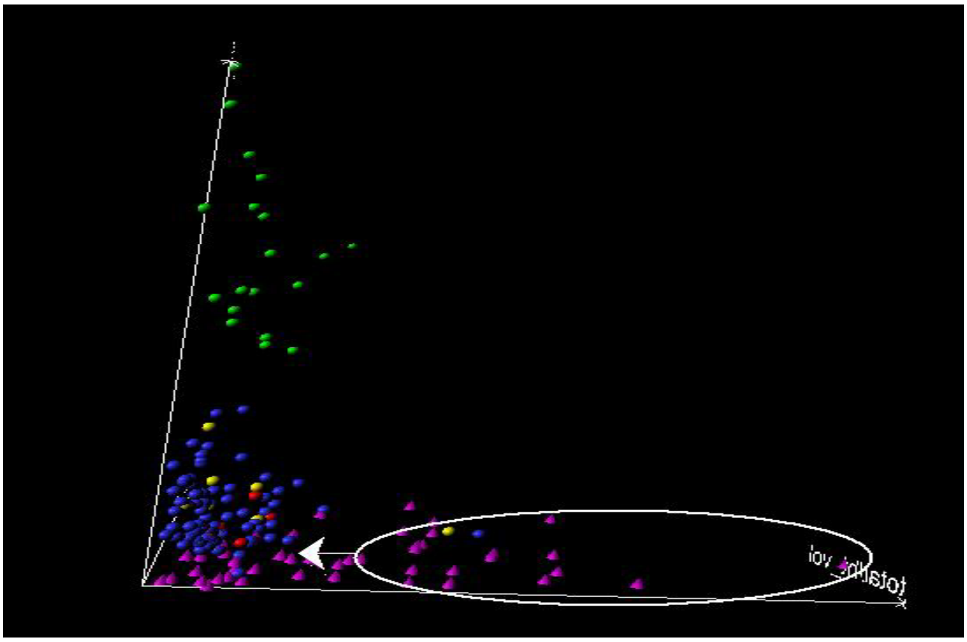


Figure 4-33 Heating volume ('ht_vol') v. unit energy consumption ('total/ht_vol').

When it comes to the assessment of the effects of the energy strategy and tactics, however, the pattern identification is restricted in a specific aspect of the two dimension data space. In two dimension data space, data dots from different groups are likely be superimposed, which makes it hard to see the patterns (e.g. small education properties and social service properties Figure 4-31). On the contrary, comprehensive perception can be obtained from three dimension data space of which the angle can be changed with the user interactive interface.

Figure 4-34 presents the overview of the 3D data spaces where the energy patterns of the groups of properties are seen clearly and clustered according to the types of the properties. For example, it is perceived that the secondary schools have a pattern indicating larger energy demand, yet better performance. Through the 3D view the effects of energy actions can be assessed in both strategic and tactical aspects. For example, the adoption of low energy systems or renewable energy systems to education properties may affect total energy consumption, which results in shifting the energy patterns closer to the origin alongside the 'total' consumption axis (see yellow arrow). The new energy policy for the better energy efficient buildings with energy motivation schemes may improve the energy performance patterns alongside the total consumption/heating volume axis (see light blue arrow).

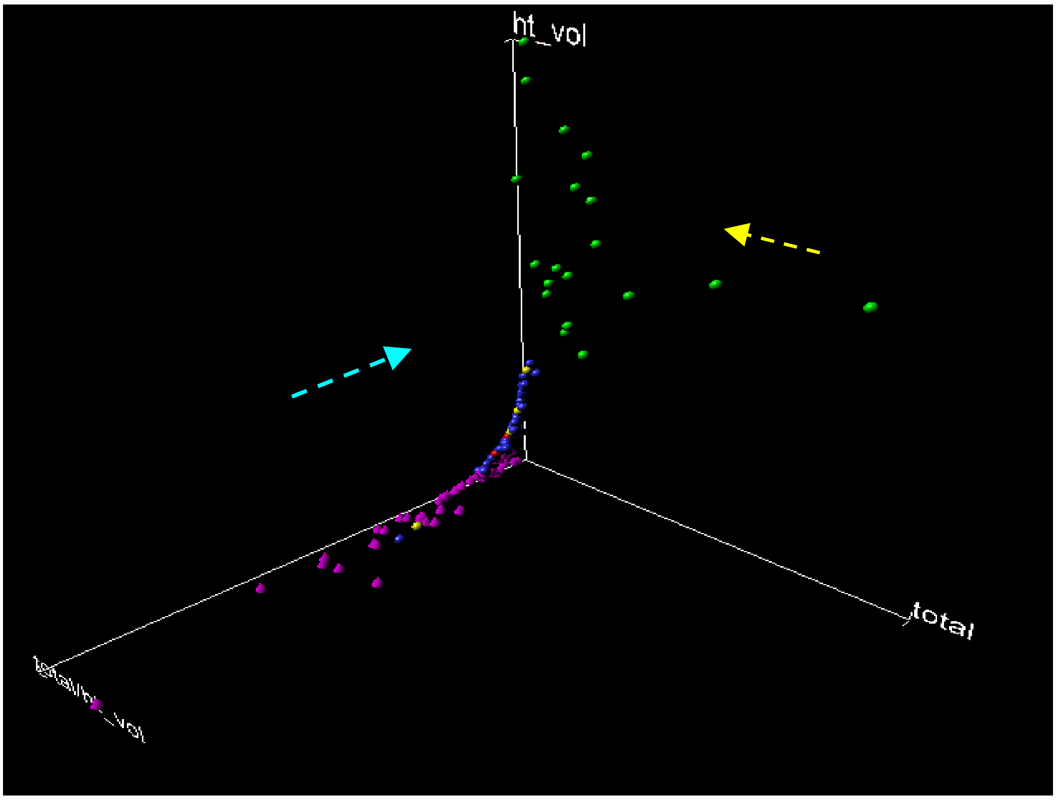


Figure 4-34 The overview of energy consumption pattern

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Chapter 5 EEIS Prototype: Specification of the System Connectivity

A number of modelling techniques, including detailed building simulation, renewable energy systems modelling, statistical models and GIS models, are involved in decision-making for energy planning. In practice, such modelling techniques cannot be effective unless decision-makers possess the necessary expertise and access to reliable input data. To overcome this deficiency, decision-making should be made in a collaborative way. It is possible to integrate distributed information resources within the EEIS in order to set up a collaborative decision-support system. The main concern is not the nature of modelling techniques, but how to integrate existing systems, which might then be regarded as a component within the EEIS. Integrating monitoring and control systems in the EEIS is also important in terms of obtaining real data supply channels. Advanced electronic communication technology is bringing new capability to energy demand/supply management by allowing real-time operation based on high quality data.

In order to make a fully integrated system, the system connectivity must meet the following requirements:

- on-line operation allowing real-time data transaction without intermediate media and human intervention;
- interoperable two-way data/control communication streams, commissioning modelling and returning the result to users in an interactive manner; and
- sharing a common database retrievable by different component types (e.g. modelling and monitoring/control system).

In this chapter, the following approaches to EEIS connectivity with third party systems are elaborated.

- o Coupling with GIS has examined the database connectivity and the program invocation for GIS-based energy map model production.
- o Coupling with ESP-r (ESRU 2002) demonstrates an on-line integration between the EEIS and a detailed simulation program when used to generate virtual data. The data connectivity and transforming mechanism between ESP-r outputs and EEIS components have been made. Their application for Internet-based collaborative modelling is discussed.
- o Coupling with an e-service system supports an on-line energy service system. The data/control transmission mechanism is developed and verified to test the feasibility of the system.

5.1 GIS-based Energy Map Model

Figure 5-1 illustrates the data connectivity and procedure for the GIS-based energy map model. The process model is based on the analysis process model described in Section 4.3 (i.e. a data aspect model). The architecture of the process model is constructed with a data aspect model, a GIS model and map views. Firstly, to create the data aspect model, the entity data and energy-environment data are defined by selecting data from the EEIS database and registering these data as a data source in the data pooling tier. The entity data and the energy/environment data are then joined into a virtual table of the data aspect model. This virtual table is then used as an entity attribute for the GIS model.

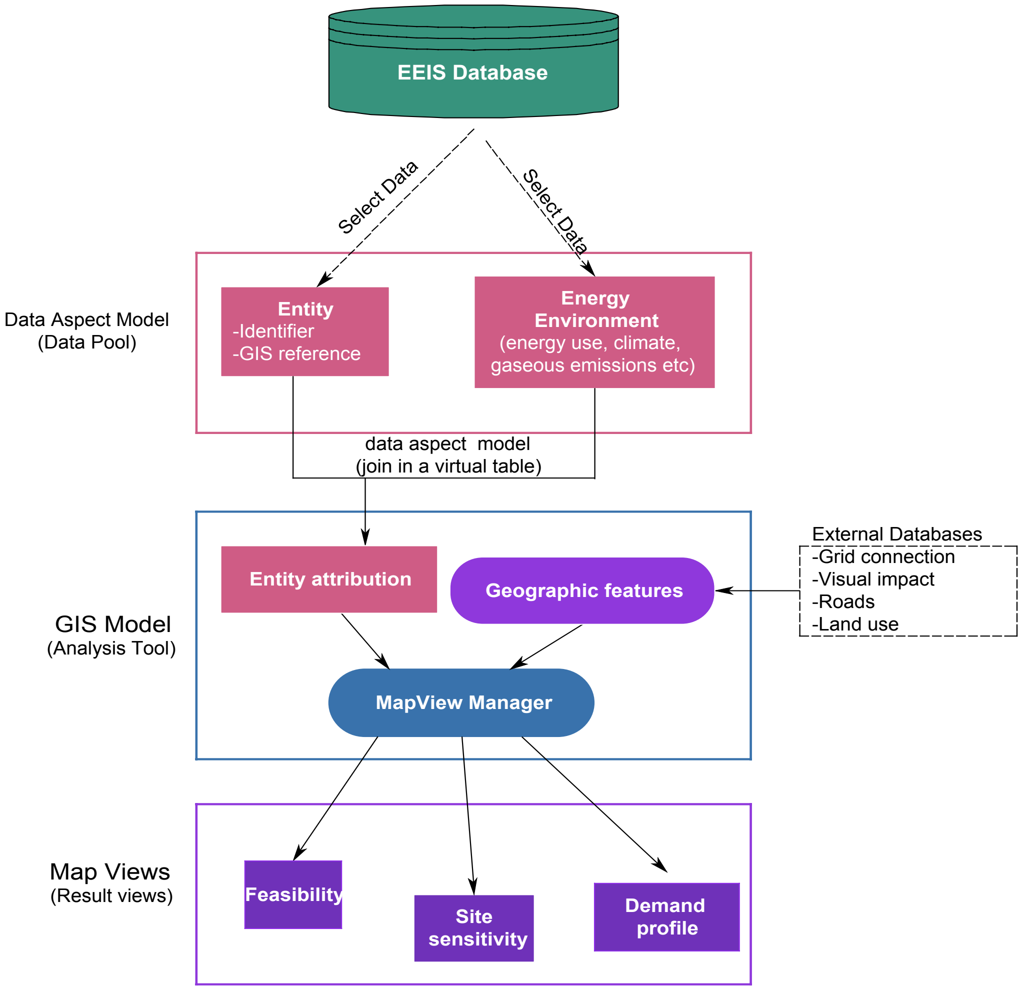

Figure 5-1 The data connectivity and procedure of GIS-based energy data views.

The GIS model is defined by linking the entity attribution to geographic features (i.e. spatial data model). The attribute table for the GIS model, which is defined above, contains x y co-ordinate data (i.e. field name of 'gis_xref' and 'gis_yref') and post code (i.e. 'post_code'). Those fields are used as the geographic position data. Meanwhile, the geographic features are implemented in a spatial data model (e.g. coverage, grid). A GIS map model consists of several layers of the attribution and the spatial data models. Accordingly, the map view manager of the GIS application organises various map views using the entity attribution and the spatial data model.

Figure 5.2 shows an example of the GIS-based energy map model for identifying energy use. This corresponds to the Springburn district of Glasgow.

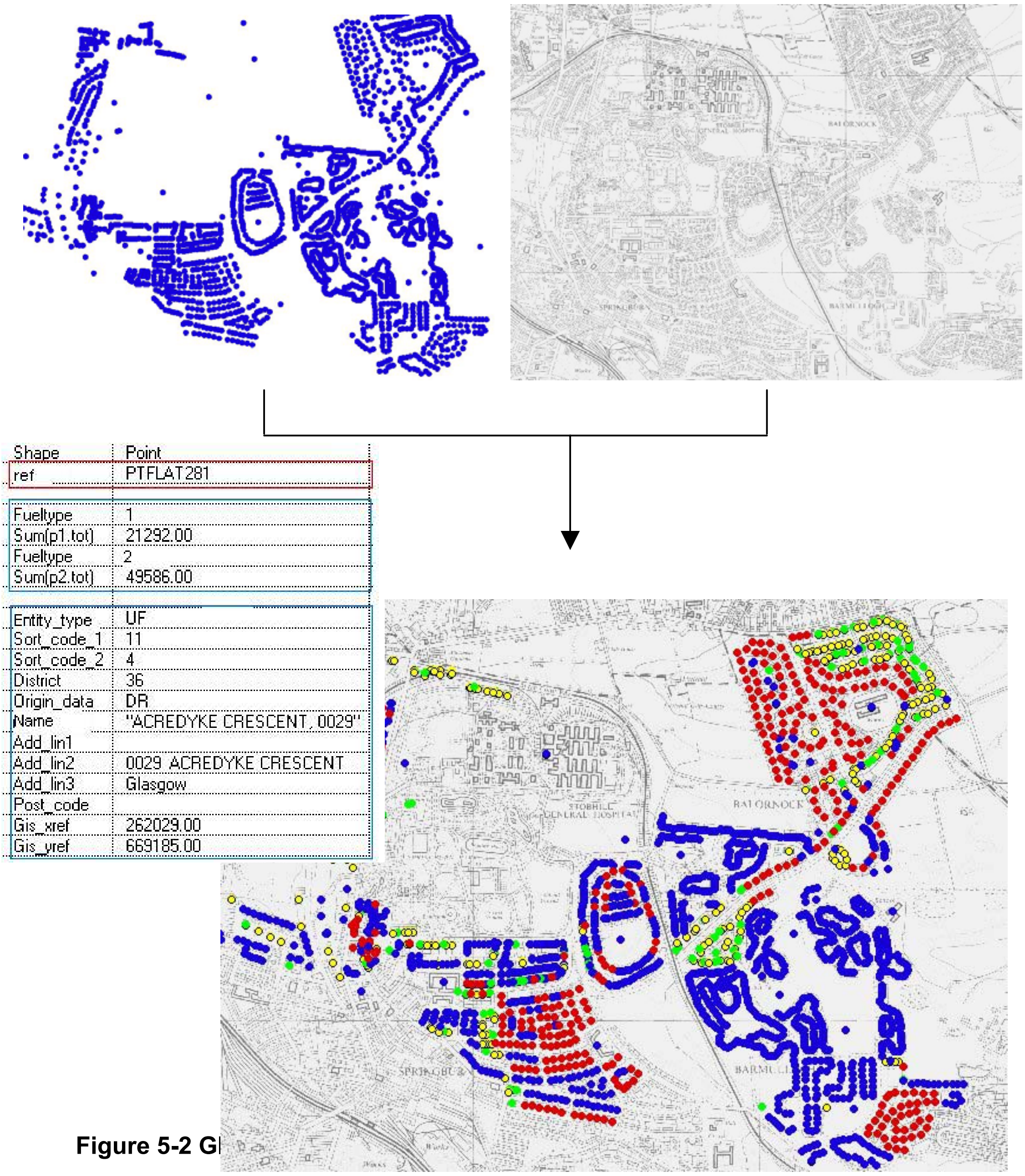

Figure 5-2 Gl

The attribution table was made by joining an entity data table and an energy data table using the 'ref' field.

For the map theme, an image file created by scanning a map is adjusted to the geo-reference co-ordinates, which matches that of the entity data. Appendix E explains how to register an image file to a geo-referenced map. Alternatively, the map coverage data model provided by GIS software vendors could be used. However, possessing and maintaining the geographic information is high cost and requires expertise. Organisations such as local councils centrally manage their resources within a single department (e.g. planning or IT). To establish an inter-department information sharing system, ODBC-based databases may be exploited as the intermediate medium.

Once the GIS model has been established, various outcomes can be presented by the GIS application software. The view at the bottom of Figure 5-2 shows the distribution of electricity use within Springburn. Likewise, the distribution of gas use can be identified.

In order to operate this data connectivity in an on-line context, an integrated interface is required to manage the invocation of the GIS application package as well as the data transaction between the EEIS database and the GIS application package. Recent technological advances in network computing offers appropriate measures for this invocation. For instance, a Java API, 'Runtime', in the java.language package is a simple way to invoke an application package on any platform. This API is used for the system integration in EnTrak as described in Chapter 6. The applicability of the GIS energy map model is discussed in Chapter 7 where EnTrak case studies are presented.

5.2 On-line Integration of Simulation Modelling Programs

5.2.1 System Connectivity

To implement the on-line integration of simulation modelling program, the ESP-r system, developed by the Energy Systems Research Unit at the University of Strathclyde (ESRU 2003), was adopted. ESP-r is able to undertake the integrated performance modelling of buildings (i.e. thermal performance, indoor air quality, lighting etc) and associated energy supply systems (i.e. conventional and renewable plant). Further, the Unix basis ESP-r gives effective opportunities for on-line system connectivity with the EEIS.

The data communication between ESP-r and the EEIS has been established on the basis of the SQL-based database connectivity. In the approach, data transformation is a critical issue in order to make the ESP-r data retrievable over the Internet. Fortunately, simulation result data is easily transformed to SQL format because it has a time series structure. By using the SQL communication protocol, the data generated from the ESP-r engine is exported to the EEIS via the Internet. This is implemented by activating a SQL command within the ESP-r program. The resulting data can be imported to the EEIS database in a corresponding data table (e.g. building, energy, indoor environment, climate etc). The following SQL statements are embedded within the ESP-r program code.

REPLACE INTO indoor_climate (ref, ic_code, datetime, ic_item, value) VALUES (*zone_id* , 'ESP', *dt, db, tma*);

REPLACE INTO energy (ref, meter_id, fuel_type, r_type, to_datetime, dial_1, tot) VALUES (*zone_id* , 'HF','HF','ESP', *dt, qm,qm*);

Here, the values of 'zone_id', 'dt', 'db', 'tma' and 'qm' are obtained from the ESP-r simulation program; 'zone_id' is defined by a project name and zone id number.

The schematic building information is recorded in the entity and building table of the EEIS database. The basic information on a zone, for instance, is sourced from the summary file available in the QA reporting facility of ESP-r. A zone in a modelling project can be defined as an entity with a zone ID number and the simulation project name in the 'ref' field, and the entire building model consisting of several zones is registered with the project name in the 'building_ref' field. The notable characteristics of the modelling exercise (e.g. design options) may be coded and stored in the 'sort_code' fields in the building table. The following SQL statements are examples of the registration of the entity in the EEIS database. Figure 5-3 shows the summary file of a simulation model of which part information is exported to the database using the following SQL statements.

INSERT INTO entity (ref, name, origin_data, entity_type) VALUE (‘FEDERICK_01’, ‘rest1_1’,‘DV’ ,’BD’);
INSERT INTO building (ref, building_ref, ht_volume, ht_flr_area, transp_area, opaque_area) VALUE (‘FEDRICK_01’,’FEDERICK’, 99.9, 37.0, 35.2, 105.7);

```
cfg: FEDERICK.cfg
project: refurbishment, restaurant and kitchen, basement floor at Federick st.
print date: Fri Jul 25 15:18:27 2003

ID Zone           Volume|          Surface
   Name            m^3   | No. Opaque  Transp  ~Floor
 1 rest1_1         99.9  13   105.7    35.2    37.0  near  the entrance in restaurant 1
 2 rest1_2         75.6  12    85.9    27.4    28.0  down area of restaurant 1
 3 bar            216.0  20   208.6    48.6    80.0  bar
 4 rest2           86.4  13   101.3    27.5    32.0  rest2 describes restaureant 2 area
 5 court          187.9  18   133.0    95.7    61.6  court describes a... court area
 6 kitchen        104.5   8   140.9     7.2    38.7  kitchen describes a kitchen
 7 wc             104.5   8   145.9     2.3    38.7  wc describes a... toilet  area
 8 first_1         74.3   8   107.9     1.6    24.8  first_1 describes a... first floor 1
 9 first_2         74.3   8   108.3     1.2    24.8  first_2 describes a... firstfloor 2 a
10 hotel          943.4  11   647.2     0.0    81.7  hotel describes a...rest of new hote.
from modelli
11 corridor_1      41.9   8    71.8     1.7    13.9  corridor_1 describes a...corrider of
12 corridor_2      41.9   8    71.9     1.6    13.9  corridor_2 describes a... corridor a:
floor
13 office        2247.7   7  1012.0     0.0   169.0  office describes a...office building
restaurant
   all           4298.  142   2940.    250.    683.
```

Figure 5-3 ESP-r summary file.

Significantly, the simulation predictions can be transferred to the EEIS at each time step of the simulation through an SQL communication protocol. This feature allows various applications such as network-based modelling process or real-time based interactivity between real entity and virtual data (e.g. control algorithms based on the virtually predicted data). For example, the predictive control using a physically-based thermal simulation program (Clarke et al 2002) requires real time monitored data to be used as input parameters for the simulation process. The simulation results (e.g. the optimum start time) must be informed to the control devices at a certain time step or every time step. The real-time input data from sensors and the simulation results could be transmitted between devices and simulation programs via a database server.

As the simulation results data and entity data are sent to the EEIS database, the virtual data can be broadcast immediately to other systems (e.g. analysis tools, control systems, a Web user interface etc) via the EEIS database server. Such a network-based building simulation environment will enhance the efficiency of the communication and cooperation between parties involved in a simulation project. The following section describes an application of the Internet-based integration of a building simulation package in the EEIS for supporting network-based, collaborative, decision-making.

5.2.2 Application of Collaborative Simulation Modelling

A detailed simulation modelling project is usually carried out as a collaboration between several individuals. For instance, a building designer may commission a modelling team consisting of a project manager and a simulationist. The project manager verifies the model made by the simulationist. The designer is often asked to provide relevant data required by the model. A reliable and acceptable model is obtained as a consensus between the project manager, simulationist and designer. This requires a series of technical exchanges and model reviews. However, the designer often has difficulty reviewing the model due to a lack of knowledge about the operation of the modelling tool being used. Providing a user-friendly reviewing tool is therefore an important part of improving the efficiency of collaborative decision-making.

An on-line review system makes it possible to review schematic results in real-time. The data communication between ESP-r, the EEIS database sever and the Web service system interface has been established, and a Web-based modelling reviewer designed. Figure 5-4 illustrates the data connectivity and procedure of the on-line review system. Once an initial simulation model is generated by the simulationist, the building's geometry, weather context and simulation results may be transferred to the Web server domain and the EEIS database. The model and the simulation results are eventually broadcast by the Web server over the Internet using the HTTP protocol. This allows various types of content, including multi-media objects, to be delivered to Web clients. The purpose of the integration agent is to manage any data query from the database and co-ordinate the data transaction between the Web server and the ESP-r system.

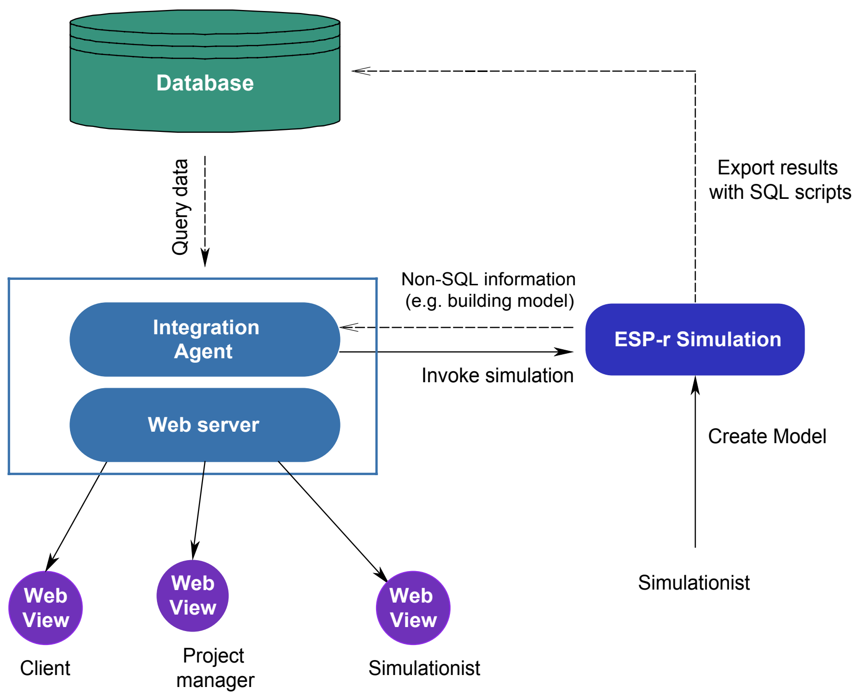

Figure 5-4 The architecture of on-line modelling review system.

The building geometric model is a crucial target in simulation modelling. Enhancing user interactivity with the building model will improve the modelling process and help make a valid model. It is important to present the building model in a user-friendly manner to those who are not familiar with the modelling system (i.e. designers). As the ESP-r building model contains attribution data as well as geometric data, the capability of reviewing such information in an efficient way is also significant in terms of quality assurance. To this end, the Virtual Reality Modelling Language (VRML) has been chosen since it is a universally accepted 3D manipulation device as well as Internet-enabled (Web3D Consortium 2003). By restructuring the data format of the building geometric model in VRML, the ESP-r building model can be presented in a Web-based, user-interactive form.

In order to transform the attribution and geometric data of the ESP-r building model to VRML format, the geometric data in the '.geo' files of an ESP-r building model are reformatted. A parsing program manages this transformation automatically. The geometric data from several '.geo' files in the ESP-r zones directory are combined into a single VRML file. Figure 5-5 shows a '.geo' file of a zone, while Figure 5-6 shows the equivalent VRML file. The VRML building model can be viewed with any 3D model viewer available from various vendors.

```
  # geometry of kitchen defined in: ../zones/kitchen.geo
GEN  kitchen  kitchen describes a kitchen  # type, name, descr
    14      8   0.000    # vertices, surfaces, rotation angle
#  X co-ord, Y co-ord, Z co-ord
   18.10120    -0.32618     0.00000  # vert   1
   19.26589    -4.67285     0.00000  # vert   2
   27.57285    -2.44701     0.00000  # vert   3
   26.40817     1.89965     0.00000  # vert   4
   ……………………………….
   21.09559     0.47618     2.70000  # vert  14
# no of vertices followed by list of associated vert
  5,  2,  3,  7, 13,  6,
  4,  3,  4,  8,  7,
  5,  4,  1,  5, 14,  8,
   …………………..
  4,  9, 10, 11, 12,
  4, 14, 13,  7,  8,
# number of default windows within each surface
…………………
#surface attributes follow:
# id  surface      geom  loc/  mlc db       environment
# no  name          type  posn  name         other side
 1, to_wc         OPAQ  VERT  kit_inwall   wc
 2, external      OPAQ  VERT  stone_e_hote GROUND
………………………..
 5, floor         OPAQ  FLOR  ground       GROUND
 6, to_court      OPAQ  VERT  stone_e_hote court
 7, void_court    TRAN  VERT  fict         court
 8, ceiling2      OPAQ  CEIL  ceiling      first_1
```

Figure 5-5 Examples of an ESP-r .geo file.

```
#VRML V2.0 utf8
Anchor {
parameter [ "target = description" ]
 url [ "kitchen_to_wc.html" ]
 children [
  Shape {
   appearance DEF SOLID Appearance {
    material Material {
     diffuseColor 1 1 1
     ambientIntensity 1.0
     specularColor 0 0 0
     shininess 0.525
     transparency 0.5
```

```
    }
   }
   geometry DEF to_wc IndexedFaceSet {
    ccw TRUE
    solid FALSE
    coord DEF first_COORD Coordinate { point [
      21.09559  0.47618  2.7,
      18.1012 -0.32618 0.0 ,
      19.26589 -4.67285 0.0 ,
      27.57285 -2.44701 0.0 ,
      18.1012 -0.32618 2.7 ,
      19.26589 -4.67285 2.7 ,
      ………………………………
      22.26026 -3.87051 2.7     ]
     }
    coordIndex [
      2,  3,  7, 13,  6, -1,
    ]
   }
  }
 ]
}
```

Figure 5-6 VRML equivalent to the ESP-r geometry model of Figure 5-5

It is also necessary to view simulated data items easily to assess the simulation result before going for a more sophisticated analysis. In addition, the modelling analysis program may generate the visualised outcomes, for example, associated with lighting analysis. ESP-r has the option to invoke a RADIANCE analysis and orchestrate image outcomes. A series of image files presenting time-based results can then be used to provide animations. Although the analysis process requires expertise, the outcomes may be shared over the Internet between members of the design team.

Figure 5-7 shows an example of an ESP-r model in the Web-based model reviewer. As can be seen, users can perceive the geometric model from different angles in the VRML model viewer (Parallel Graphics 2003). Since the VRML model viewer provides URL links on the surfaces of the model, the basic information of the zone appears on the adjacent page by simply pointing to a zone on the screen. In addition, the specification of a construction is linked to the name of the surface so that it can be detailed in another window by clicking on the surface name.

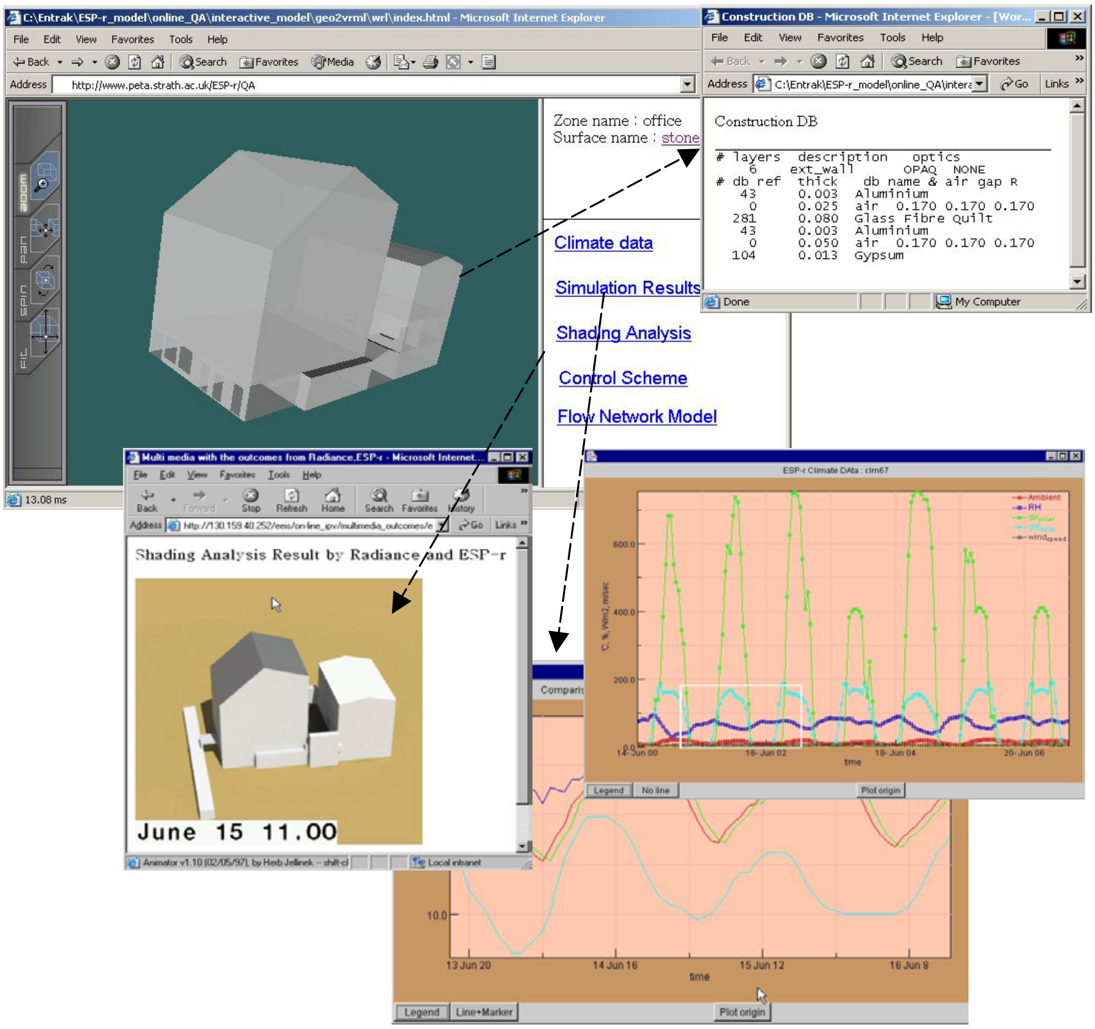

Figure 5-7 Web-based modelling reviewer.

The simulation results are displayed in a profiler. The profiler is a Java applet equipped with a JDBC driver to access the EEIS database. To deliver multi-media outcomes, such as a shading analysis produced by RADIANCE, an animator API (Jellinek 2002) has been adapted. A Java applet embedding the animator API accesses the image files and presents them in time sequenced order.

5.3 On-line Energy Service System

By integrating an e-service system within the EEIS, new types of on-line energy services are realisable with the following benefits.

- o High quality and high resolution energy/environment data can be collected via secured communication streams.
- o An aggregated information can be provided in real-time, which can be used to control an entity (e.g. demand control according to collective load trends).
- o Monitored data (e.g. micro-climate data from a local weather station) may be broadcast to all clients in the service network in real-time.
- o Ultimately, the interactive demand/supply management will be possible in a micro-grid where the monitoring/control systems are installed, and appropriate control algorithms (e.g. switching supply channels according to demand profile) are deployed.

As illustrated in Figure 5-8, the architecture of the prospective on-line energy service system is constructed by combining the monitoring/control devices, the e-service system (refer to 2.3.2), the EEIS database and the Web service system.

A gateway-based monitoring/control system comprises an electronic gateway (e.g. e-box), sensing/actuating devices and their base station to monitor energy/environment data (e.g. temperature, humidity, movement, CO, power etc), and to impose actuations (e.g. switches). The monitoring/control system is installed at sites that may be houses, buildings, factories or renewable energy schemes at any scale.

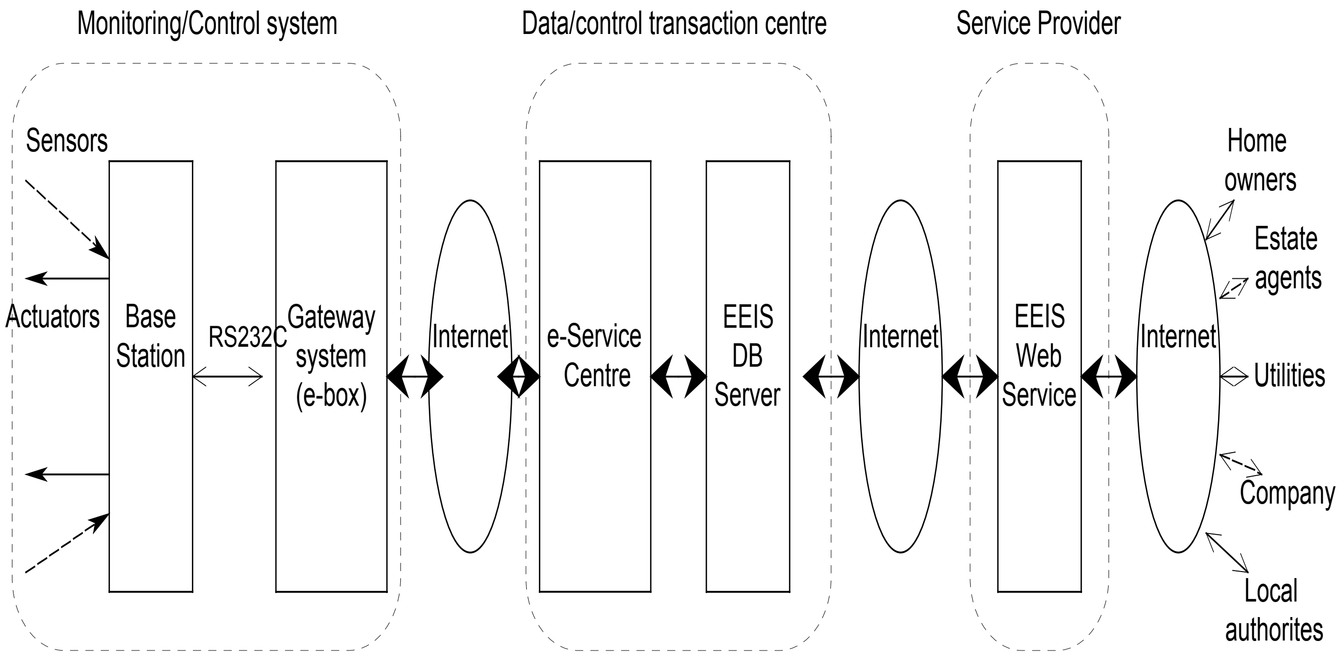

Figure 5-8 Architecture of the prototype of on-line energy service system.

Although the devices are connected to the base station physically, they are directed by the control program in the gateway system. The base station is a signal distributor passing data from the gateway to several devices. This kind of distributor is required not only because the communication port is RS232, which cannot handle multi-channel communication simultaneously, but also because there are many different types of devices (most significantly wireless or wired) and communication protocols (e.g. IP based, non IP-based) to be connected to the gateway system.

Therefore, the communication protocols between the gateway and the base station (i.e. the devices) are also variable depending on the vendors of the devices. As the vendors usually have their own protocols, they provide the instruction codes, the so-called 'data sheets', to allow customers to control their devices. In the context of the EEIS, this flexibility gives more opportunities for including existing energy/environment management systems into the network of the on-line energy service.

The role of the gateway is to serve as a bridge between monitoring/control devices and external systems located remotely on the Internet. In addition, the gateway system can also control the devices locally in the case where a control algorithm is deployed in the system. This feature allows smart control co-ordinating external information. For example, heating systems can be operated as a function of building thermal inertia and predicted weather condition.

The communication between the gateway-embedded program (so-called 'bundles') and the e-service server must be secured and interactive. Therefore, popular application protocols such as telnet, HTTP, FTP and SMTP are not allowed. Instead, either the encrypted messenger service provided by an OSGi-compliant package or a bespoke protocol must be used.

The e-Service centre and the EEIS database are operated in the data/transaction centre where data transactions between the monitoring/control systems and the service providers are made. The e-service centre controls all communication with the distributed e-boxes. It receives data from the e-boxes and passes it to the EEIS database server, which stores the data in the EEIS database table and makes it retrievable. The role of the EEIS database server is to supply its data resource to energy service providers. Both servers are principally managed in a secured network (i.e. firewall) while the communication is established with the SQL protocol.

The energy service providers in the service provider domain offer different products according to the requirements of end-users who may be utilities (e.g. automatic meter reading, demand/supply control), home owners (e.g. remote home appliance control, health and safety), local authorities (e.g. large scale data management, sophisticate analysis commissioning), or companies (e.g. gas trading information). The Web-based service system possesses functionalities that enable it to:

- offer analysis tools (e.g. modelling programs, GIS maps etc) with properly aggregated data;
- broadcast the relevant information to subscribing users; and
- provide end-users with interfaces for monitoring and control.

An example of the Web-based service is given in Section 6.3. To implement their own service, the Web service systems request data aspect models from the EEIS database server using the SQL database connectivity. Different information services can be carried out using the same data resource.

As described above, each system component of the on-line energy service system acts as an independent node of the information route on the network, while data must be transferred through various communication protocols between the nodes. As a number of hardware and software systems are involved in this route, establishing the data transmission between nodes is not trivial, and yet it is the most crucial issue to realise the real-time network integrated service system.

A laboratory prototype was constructed to test the feasibility of the on-line energy service. Communication software was developed for a laboratory test to verify the data transmission between the nodes of the network architecture. The following sub-sections describe the implementation and the result of this laboratory test.

5.3.1 Devices and Communication Software

For this test, two types of data acquisition and control system were employed: Delta Logger system (Delta T device Ltd 2002) and a proprietary system called 'ADAM' (ESIS Pty Ltd 2002). The Delta Logger has 60 channels for receiving analogue signals from sensors. The logger was used to implement serial port communication between sensors and the residential gateway device. The Delta logger is controlled via messages sent through the RS232 serial port based on the command protocol supplied by the vendor. The appearance of the Delta logger is shown in Figure 5-9.

Figure 5-9 Delta logger system.

The second system is a proprietary system that comprises a sensor-to-computer interface module containing an in-built microprocessor. Sensors are addressed through a set of commands issued in ASCII format and transmitted in RS-485 protocol. The command set provides signal conditioning, isolation, ranging, A/D and D/A conversion, data comparison and digital communication functions. An experimental monitoring and control system was established comprising a temperature sensor (PT 100 type) and controller (a digital I/O module and RS485/RS232 converter). The experimental system is shown in Figure 5-10. An e-service gateway, or ‘e-box’, has been exploited as the gateway device. The architecture of the experimental system is illustrated in Figure 5-11.

Figure 5-10 Proprietary data monitoring and control system.

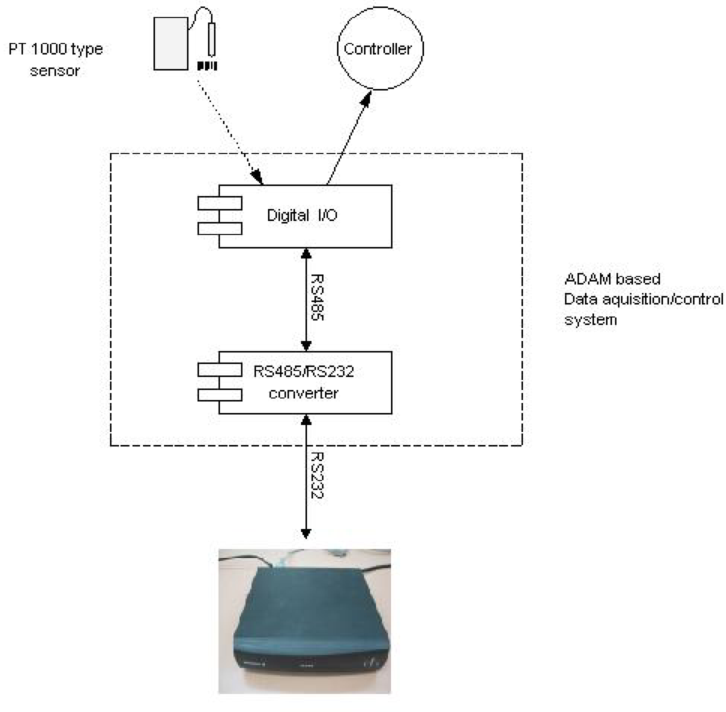

Figure 5-11 Architecture of the data monitoring and control system.

As illustrated in Section 2.3.2, the e-service centre is a complex system consisting of several servers. Since the system is not trivial in terms of installation and operation, an emulator of the e-service centre was developed for the prototyping test. The emulator is exploited only for the basic requirement, that is, passing data from the gateway system to the EEIS database server. The emulator was implemented in a server socket program. This talks to a client socket involved in a software bundle running on the e-box. The server uses a specified port for the socket communication.

An OSGi bundle, which is a software package deployable over a network running within an OSGi framework, was developed to handle the device driver and data transmission from the e-box to the e-service centre. The OSGi bundle includes communication APIs for serial port and socket. The architecture of the bundle is shown in Figure 5-12.

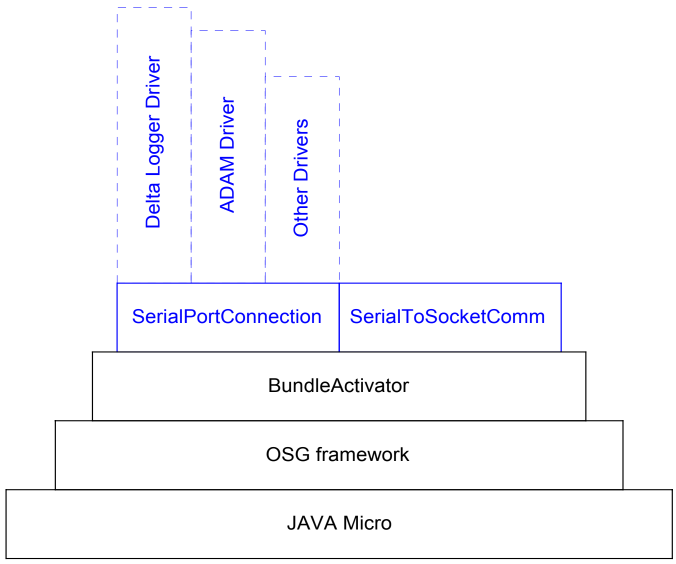

Figure 5-12 Architecture of OSG-based device driver.

The SerialPortConnection handles serial port communication that is not IP-based. The driver for each vendor's device (e.g. Delta Logger or ADAM) uses the generic communication API with its own protocol. The SerialToSocketComm API manages the data transmission from serial port to a server host. It sends the data obtained through the serial port to a server socket over the network. Serial port communication is implemented by SerialConnection API, which works in the context of the javax.comm package. Socket communication is established by the ‘Socket’ class of the java.net package.

The data is wrapped in a simple socket stream: Reference (25 byte) + ic_code (10 byte) + date (10 byte) + time (8 byte) + ic_item (8 byte) + value (20 byte).

The emulator of the e-service centre was implemented with the eServiceServer API and the SendDataToSQL API. The eServiceServer API is a server socket receiving data from the socket client of the e-box and sending it to the EEIS database. When sending data, it acts as a client of the EEIS database system. The SendDataToSQL API handles the SQL execution. An example SQL statement is given below; this adds a data record of type indoor climate table to the database of ‘smarthome’. The data record is created by parsing the data socket stream.

INSERT INTO smarthome.indoor_climate (ref, ic_code, datetime, ic_item, value) VALUES (‘esru001’, ‘living-01’,’2001-01-22 10:46:52’,’temp’, ‘25’);

The developed communication APIs are summarised in Table 5-1.

Table 5-1 Summary of communication APIs.

API	Description
e-box to e-service centre	
SerialToSocketComm	Sends data from serial port of the e-box to a host over the network through a socket client. It can be extended for specific device driver communication.
SerialConnection	Handles serial port open/close and input/output events.
e-service centre to EEIS	
eServiceServer	Sends data from socket clients to the EEIS database. It manages a socket server, EntrakProtocolModel and SQL execution.
SendDataToSQL	Manages SQL execution to send the data of EntrakProtocolModel to the EEIS database.

5.3.2 Laboratory Testing

A laboratory test was implemented to verify the prototype of the on-line energy information service system. A mock-up system was established comprising an e-box, 2 alternative data monitoring/control systems (i.e. a Delta-Logger and the ADAM system) and temperature sensors (i.e. thermocouples for Delta-Logger and PT 1000 type for the ADAM system). The configuration of the mock-up is shown in Figure 5-13. The data transactions were monitored at each node within the data route of the prototype.

Figure 5-13 The mock-up of the prototype on-line energy information service.

To deploy the required OSGi bundles to the e-box, a Web server was installed in a PC connected to the e-box because the communication between the e-box and external hosts is achieved through HTTP. The Web server of the PC issues the OSGi-bundles. Using the user interface of the e-box, the OSGi bundles are accessed and downloaded to the e-box (see Figure 5-14). The e-service centre emulator installed in a PC host serves to talk to the bundle of the data monitoring/control system in the e-box. On receipt of the data from the e-box, the emulator passes it to the EEIS database server and displays the SQL statement on the screen (see Figure 5-15). The EEIS database system has been implemented in the MySQL relational database management system (MySQL AB 2002), which runs under the Linux operating system.

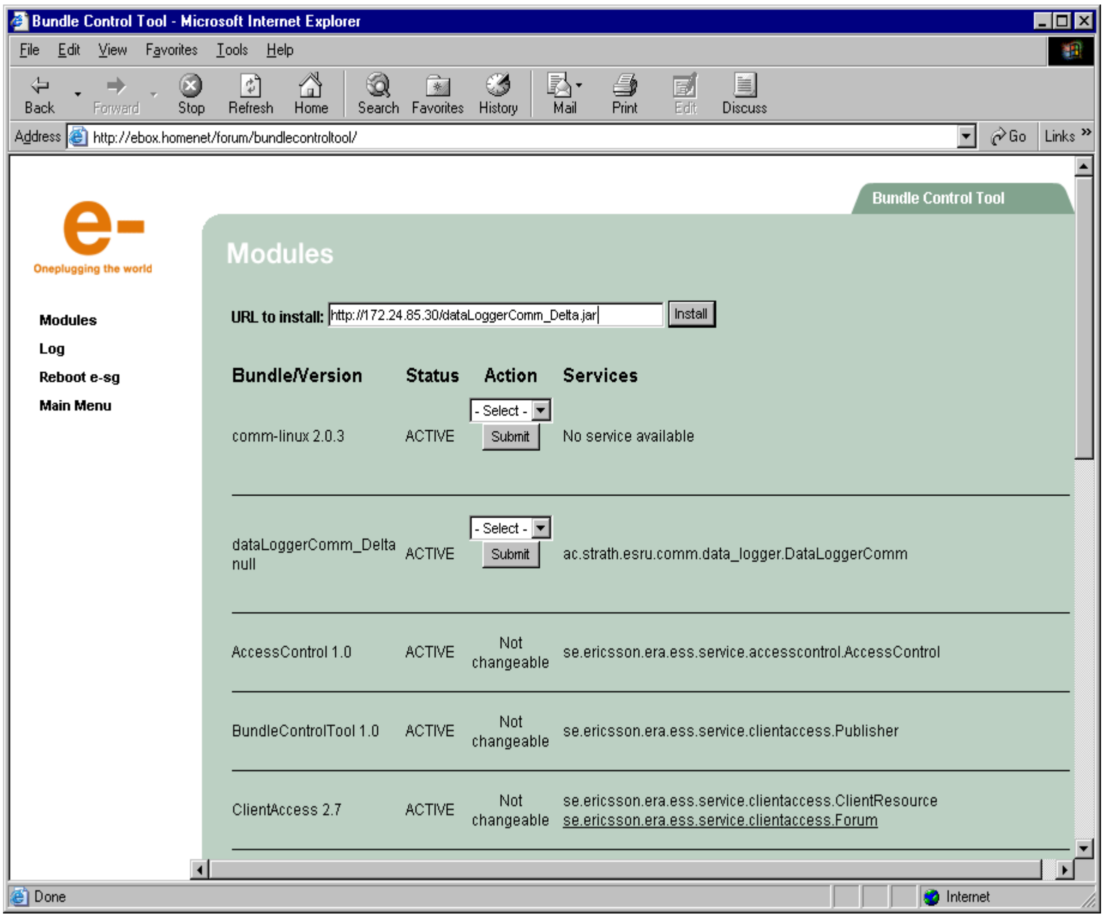

Figure 5-14 User interface of the e-box deploying OSG Bundles required for energy data monitoring/control.

```
C:\jdk1.3.1\bin\javaw -classpath "C:\smart_home\development\projects\eBoxToMySQL\classes;D:\adp\sgdk_2.1\lib\framewo
Socket accepted.Thread running:Thread[Thread-0,5,main]
2002-02-04 13:35:520001
2002-02-04 13:35:57 2 TCT      temp    19.17 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:02 2 TCT      temp    19.17 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:07 2 TCT      temp    19.17 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:12 2 TCT      temp    19.19 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:17 2 TCT      temp    19.97 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:23 2 TCT      temp    20.49 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:28 2 TCT      temp    20.83 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime       :, ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:33 2 TCT      temp    23.66 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:38 2 TCT      temp    23.75 deg C
INSERT INTO indoor_climate(ref, ic-code , datetime        , ic_item, value) VALUES ( 'smarthome001','living-01','2002-0
2002-02-04 13:36:43 2 TCT      temp    23.80 deg C
```

Figure 5-15 e-service server emulator in operation.

A Web server is installed in another host on the experimental network where the e-service server emulator and the EEIS database server run. The J2EE system has been adopted as the Web server due to its capability to handle dynamic Web pages and multiple database connectivity. A Web application was established to access the laboratory prototype. The Web application delivers energy information to users on demand over the Internet after obtaining the data resources from the EEIS database server.

Figure 5-16 shows the J2EE Web application deployment tool for configuration of the Web application.

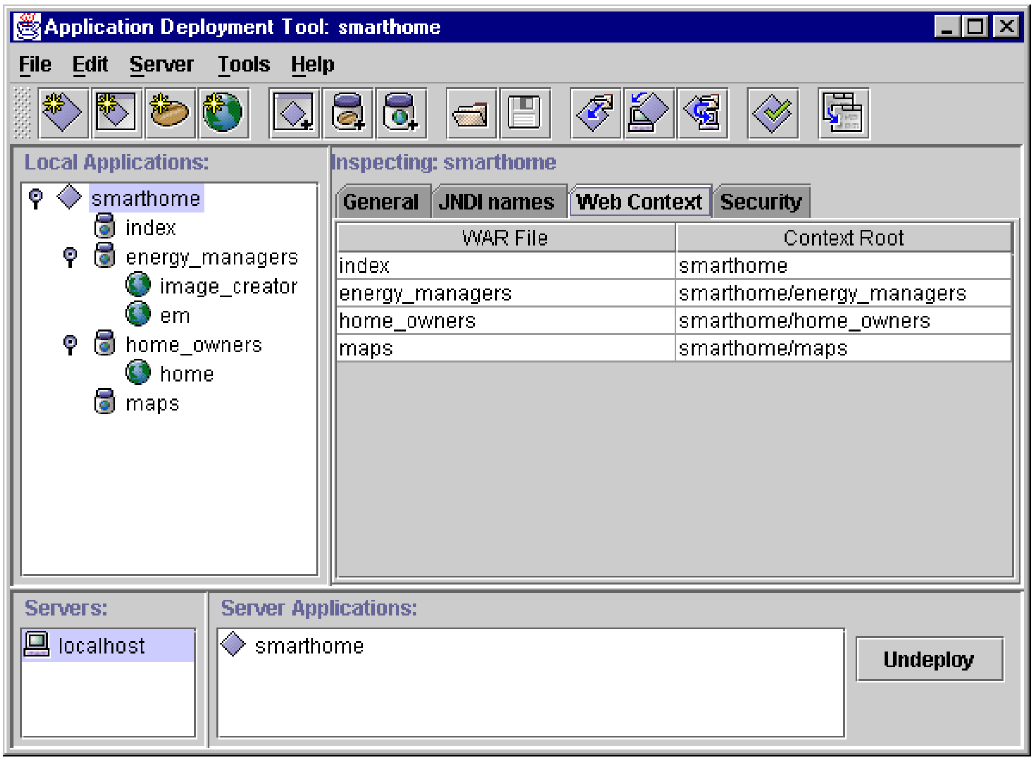

Figure 5-16 J2EE Web application deployment tool

```
[min@peta /usr3]$ mysql -u manager -p -h localhost
Enter password:
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 38 to server version: 4.0.0-alpha

Type 'help;' or '\h' for help. Type '\c' to clear the buffer.

mysql> select * from smarthome.indoor_climate limit 10;
+--------------+-----------+---------------------+----------+--------+
| ref_ref      | ic-code   | datetime            | ic_item  | value  |
+--------------+-----------+---------------------+----------+--------+
| smarthome001 | living-01 | 2002-02-04 13:36:43 | temp     | 23.800 |
| smarthome001 | living-01 | 2002-02-04 13:36:38 | temp     | 23.700 |
| smarthome001 | living-01 | 2002-02-04 13:36:33 | temp     | 23.600 |
| smarthome001 | living-01 | 2002-02-04 13:36:28 | temp     | 20.800 |
| smarthome001 | living-01 | 2002-02-04 13:36:23 | temp     | 20.400 |
| smarthome001 | living-01 | 2002-02-04 13:36:17 | temp     | 19.900 |
| smarthome001 | living-01 | 2002-02-04 13:36:12 | temp     | 19.100 |
| smarthome001 | living-01 | 2002-02-04 13:36:07 | temp     | 19.100 |
| smarthome001 | living-01 | 2002-02-04 13:36:02 | temp     | 19.100 |
| smarthome001 | living-01 | 2002-02-04 13:35:57 | temp     | 19.100 |
+--------------+-----------+---------------------+----------+--------+
10 rows in set (0.00 sec)

mysql>
```

Figure 5-17 The data measured from the mock-up system in the EEIS database.

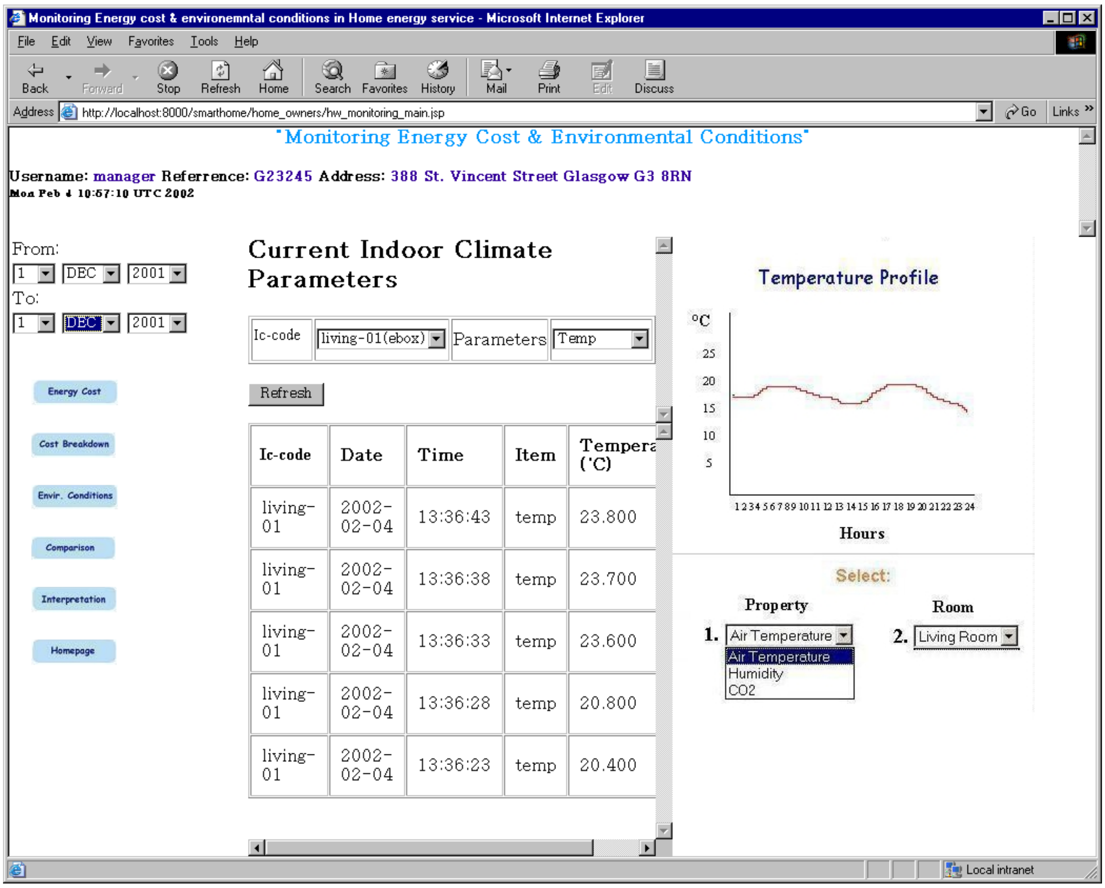

Figure 5-18 Displaying the data of the EEIS on a Web interface.

Once the component systems have been set up, the operation is started by launching the service-specific software bundle in the e-box. A series of temperature measurements in the mock-up system were entered into the EEIS database, which was confirmed by querying the data with the MySQL client program as shown in Figure 5-17. Eventually, the data was displayed in a Web page as shown in Figure 5-18. This confirmed that the data transaction of the prototype was established successfully.

Based on this communication infrastructure, the full-scale operation was achieved by deploying a number of e-box monitoring/control devices in the field. This field deployment was undertaken as part of an EC project, ‘On-line Energy Service for Smart Homes’ (Clarke et al 2003). This project developed an on-line energy service delivery system. The server emulator (e-sc) was replaced with the e-service centre as the core data manager dealing with the data transactions between the e-service system and monitoring/actuation devices located within homes. The data communication between the e-box and the e-server centre was implemented through the secured SMTP instead of the socket data stream. Field testing on the full-scale communication infrastructure was initiated to investigate the ability to handle large-scale monitoring/control issues:

- robustness in long term operation;
- performance affected by network traffic congestion;
- database capacity in manipulating high frequency monitoring data (e.g. 30 seconds);
- interactivity with proper response time for efficient control actions (e.g. issuing alert messages); and
- data sorting mechanisms for delivering data aspect models requested by various service providers.

Encouraging people to save energy, the ultimate achievement of an energy awareness and motivation strategy, may best be achieved by keeping end-users well informed and providing them with timely energy alerts. How this might be achieved has been demonstrated by integrating the end-users interface within the on-line energy service. To this end, a Web-based user interface has been designed as described in Section 6.3.

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Chapter 6 The EnTrak System

The EnTrak system was developed as a software implementation of the prototype EEIS system. Due to the capability of network computing programming, Java technologies were mainly exploited for the implementation of the user interfaces, communication, analysis, data connectivity, data management, integration of modelling software and system operation. The architecture of EnTrak was designed to meet the requirements of multi-user interfaces and distributed information resources management. As illustrated in Figure 6-1, the system architecture was arranged in 3 tiers: database, process and user interface. The three tiers are connected to each other for data/control access via Internet-based communication streams. While the components of each tier are independent from those of other tiers, data transaction is established through system interfaces. Such an open structure makes the system connectivity of EnTrak more flexible and extensible so that more than one database server can be connected to provide data storage and retrieval, and different types of user interfaces can be implemented to match different data aspects from the databases.

Based on this three tier structure, two software systems were implemented: a Web based client and a stand-alone application. The Web system provides users with a user interface (i.e. Web pages with applets) hosted by a Web server system handling user requests to the databases. The Web client system distributes the contents of the EnTrak database to a number of end-users, who do not need substantial analysis capabilities. On the contrary, the stand-alone application is designed for system administrators and those who require more sophisticated analysis coupling with modelling systems. The stand-alone application has the features of system administration and integration agent, co-ordinating interconnection with third party modelling packages such as ESP-r and GIS. When the data and information needs to be administrated under the secured system environment, and data collection has to be managed locally, the application system is deployed in organisations where data transmission and information presentation are made through exclusive and authorised communication channels.

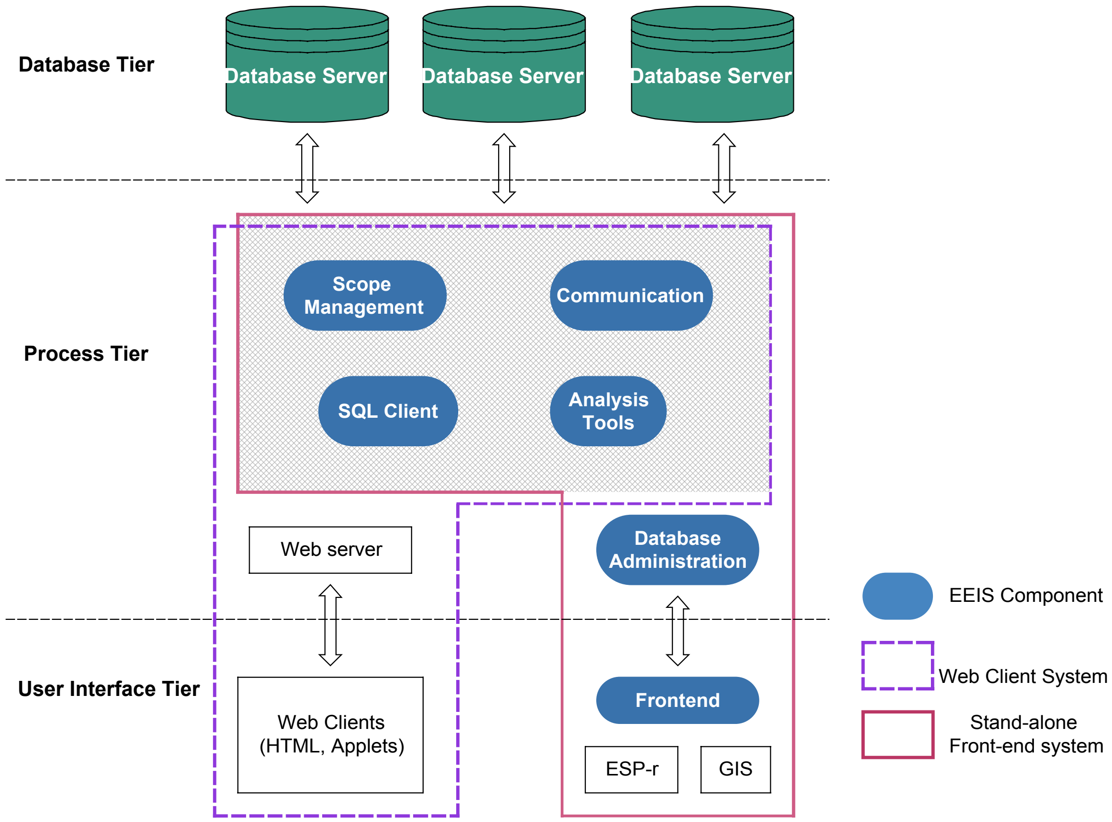

Figure 6-1The architecture of EnTrak.

While the two types of user interface are constituted separately, they are supported by a middle-ware system in the process tier to access the databases available in the database tier. This middle-ware system can respond to requests from both user interfaces. The middle-ware system comprises several components such as a scope manager, SQL client, communication and analysis tools. The components commonly shared by user interfaces ensure better opportunities for efficient system maintenance and operation. In other words, a component in the middle-ware is associated with both user interfaces at the same time. The following sub-sections describe the software API packages, the stand-alone application system and the application of Web-client system.

6.1 API Packages of EnTrak system

The API packages of the EnTrak system were designed to be applicable to any client system whether Web-based or stand-alone. Enhancing the portability of the components makes it possible to construct user interfaces within an integrated system. The following design principles were adopted in implementing these generic APIs.

- Separate GUI elements from core codes. Any API is not allowed to display a GUI component on a server. If any API with GUI elements is forced to run in the server-side, a security exception error occurs. To make sure that the APIs work in both the Web-server environment (i.e. J2EE platform) and the stand-alone application, any graphic elements must be implemented separately from the core codes of the APIs.
- Use buffered image. When dealing with graphical outputs in the core codes, the graphic outputs are stored in memory (i.e. so-called off-screen imaging). Because it is created in a buffered memory, images do not need to be displayed immediately on the screen. Using the buffered image, analysis tools making graphs can be used in both the Web system and the stand-alone package.
- Identify operating system environment. In the case where a component is used in both the Web system and the stand-alone package, the APIs must respond differently to the request from the user interface system according to the type.

6.1.1 SQL Client Package

The database system of EnTrak is an SQL-compliant DBMS, which corresponds to a client/server architecture. The components that need to access the database require the client part of the DBMS. The purpose of the SQL Client package is to manage the SQL database client-side processes, including database connection, SQL statements execution and result data table handling. The architecture of the SQL client package is illustrated in Figure 6-2. Within the context of a connection, SQL statements are executed and results are returned. The result data-set received from the server is sorted into a data table used as a portable object containing a data aspect model. The data table may then be downloaded to corresponding analysis tools. The data table is handled as an object belonging to the 'DataAspectModel' API class.

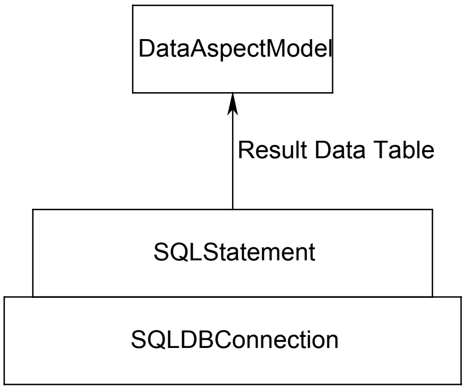

Figure 6-2 Architecture of SQL Client package.

To connect a database to the Internet, the essential parameters are the URL of the database server and the JDBC driver. User name and password are needed for the authentication unless the database is open to the public. The JDBC driver, a software package that enables the connectivity of the entire SQL database system, is available depending on the DBMS server. The driver can be dynamically loaded in the SQL client, thus re-specifying the databases to be accessed during a user session. This means that the SQL client is able to explore the databases regardless of the existence of different DBMS vendors. This feature provides significant flexibility in integrating multi-site information resources since the databases associated with the EEIS are located at several organisations using DBMS from different vendors. The summary of the SQL Client package is described in Table 6.1.

Table 6-1 Summary of classes in SQL client package.

Class	*Description*
SQLDBConnection	Manages database connection and authentication.

SQLStatement	Executes SQL statements and gets the result data from the database server. The result data set is sorted in a data model in the DataAspectModel class.
DataAspectModel	Defines and handles the data table model.

6.1.2 Database Administration Package

The purpose of the system administration package is to administer the EEIS database system. The classes in this package provide user interfaces that make it easier for users

- to edit data of tables in the EEIS database;
- to import/export data from/to files; and
- to bridge between relational DBMSs with different JDBC drivers.

Editing data for each table requires common functionality such as database server connection, SQL statement execution, data validation, window panel management, interactive spreadsheet co-ordination and error message handling.

In order to avoid redundancy, a parent API 'EditPane' has been designed. As illustrated in Figure 6-3, specific data editing APIs inherit the common functionalities of the EditPane API, adding their own functions for the specified data tables. The data editing APIs are summarised in Table 6.2. This architecture is aimed at future extensibility. Although the databases are SQL compliant, each database vendor requires its own JDBC driver. BridgeDriver API handles the data inter-exchange between different vendor's relational DBMSs, dynamically loading the vendor's data connectivity drivers.

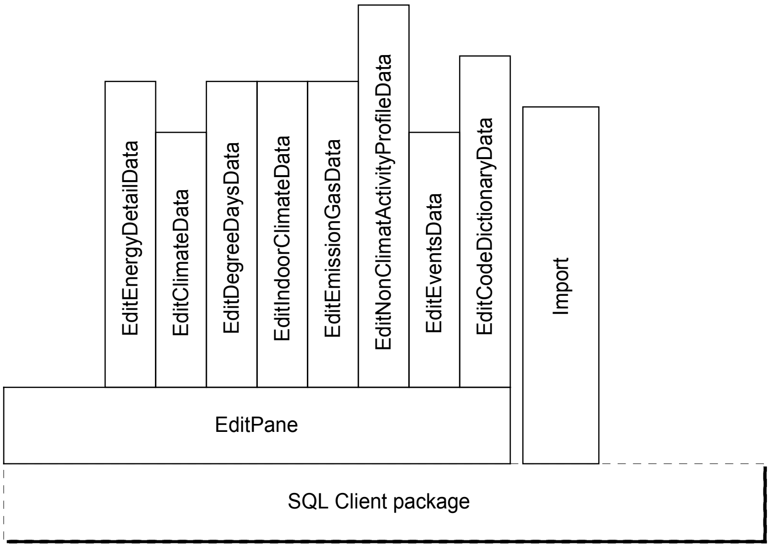

Figure 6-3 Architecture of system administration package.

Table 6-2 Summary of classes in the system administration package.

Class	***Description***
Editing data	
EditPane	is a parent class of editing data classes. It provides a
	GUI to view, update, delete data and add a new
	record. The utility methods for data validity check are
EditBuildingData	available.
EditEnergyData	edits data in building table.
EditEnergyDetailData	edits data in energy table.
EditClimateData	edits data in energy_detail table.
EditDegreeDayData	edits data in climate table.
EditIndoorEnvironementDat	edits data in degree days table.
a	edits data in indoor climate table.
EditEmissionGasData	edits data in emission gas table.
EditRefurbishmentData	edits data in refurbishment table.
EditOperationData	edits data in operation table.
EditLookUpData	edits data in code dictionary table.

Importing/exporting	
Import	import data from formatted text files.
Export	export data into file.
BridgeDriver	handles the data inter-exchange between different vendor's relational DBMSs.

6.1.3 Scope Management Package

The purpose of the scope management package is to administer scope registration and manage the scope data model described in Section 4.2. The ScopeFileManager API manipulates the scope configuration file, which stores the scope data model. The EditScopeFile API provides the user interface for creating and editing a scope definition as shown in Figure 6-4. It inherits the EditBuildingData API of the system administration API package because a scope definition is made on the basis of the building data table. The EditScopeFile API works with the ScopeFileManager API. Users can select the buildings for a scope by filtering data in the entity data table. Once the scope has been defined, it is registered in a scope registry file with the name of scope and SQL condition statements. The file is created as 'entrak/tmp/ <database_name>/<scope_name>.scope' in the local user home directory. Table 6-3 summarises the API methods.

Table 6-3 Summary of methods in ScopeFileManager class.

Methods	*Description*
SetScopeFileUrl(URL)	set the URL of a scope file.
URL getScopeFileUrl( )	get the URL of a scope file.
Boolean readScopeFile( )	read the content of a scope file .
Boolean writeScopeFile( )	write the scope data set in a scope file.
String[] sortScopeSet( )	sort scope data set.

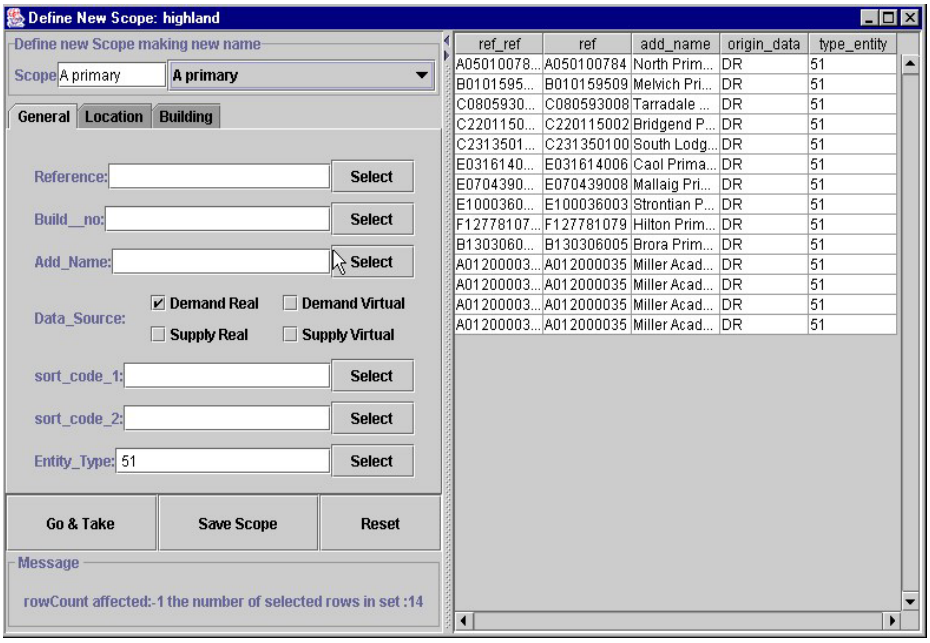

Figure 6-4 User interface of EditScopeFile API.

6.1.4 Analysis Tools Package

The analysis tools package provides graphical outcomes related to energy and environmental analysis. Although many types of graphs may be used in an energy analysis to display data (as reviewed in the previous chapter), most common of these are line graphs, scatter plots, horizontal and vertical bar charts, pie charts, tables and 3D graphs. The graphic elements are generically used by analysis tools with different data and different parameter values (e.g. the name of the x-y axis, the title of the graph, data legends etc). The outcomes of analysis tools with multiple scales and multiple views can be viewed by using the generic graphical elements and manipulating a data aspect model taken from the EnTrak database. The architecture of the analysis tools package has been designed to implement this concept. Figure 6-5 illustrates this architecture.

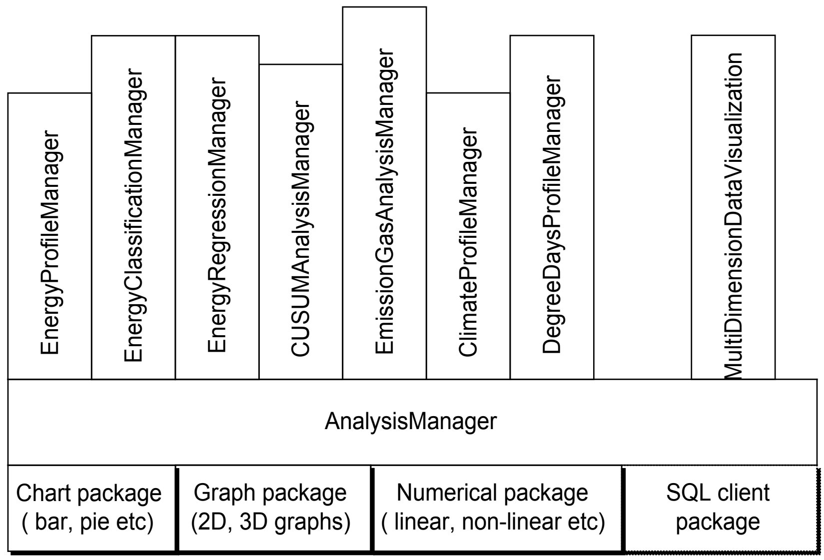

Figure 6-5 Architecture of analysis tools package.

The ProfileManager class is a parent class of the analysis tool class. It has generic functionality that handles the graphic elements, data aspect tables and calculation process. There are four packages supporting the ProfileManager class: chart package, graph package, numerical package and SQL client. The chart package provides foundational graphic elements such as vertical and horizontal bar charts. The graph package provides interactive line graphs, which can make multi-scale graphs by zooming in/out of an area on the screen. The numerical package provides elemental numerical methods, which are used for statistic modelling such as regressions, curve-fitting and so on. The SQL client package manages the data table. Each analysis tool inherits the common functionality of ProfilesManager and adds other functions for its own purpose. This architecture ensures the extensibility of the future possible development of any analysis tool. The APIs of the analysis tools package are summarised in Table 6-4.

Table 6-4 Summary of the APIs of the analysis tools package.

Class	Description
ProfileManager	Is a parent class of analysis tools. It manages option parameters (i.e. duration, fuel type, scope and frequency). It creates charts, line graph and table based on data table model selected from the database.
EnergyProfile	Profiles energy consumption (hourly, daily, monthly, yearly).
ClimateProfile	Profiles climate data .
DegreeDayProfile	Profiles degree days.
EnergyClassificationAnalysis	Classifies the buildings in a scope according to energy consumption (total, consumption/area.). It displays the result on a pie chart and a bar chart. The data table model is viewed in an interactive spreadsheet table where the data content can be sorted by descending/ascending order.
EnergyRegressionAnalysis	Make regression analysis on energy vs. degree days.
CUSUMAnalysis	Makes CUSUM analysis based on regression analysis.
EmissionGasAnalysis	Makes emission gas analysis.
Exploratory Analysis tool	
3DDataVisualisation	Visualize data model in 3 D spaces.
Foundational Graphic elements	
LineGraph	Draws lines or dots in a 2D graph. It is equipped with interactivzoom-in/out function.
LineGraph4CurveFit	Draws lines according to curve-fitting equation. It is inherited from LineGraph class.
BarChart	Draws bar chart vertically, horizontally.

PieChart	Draws pie chart.
3DscatterGraph	Plots data in a the 3 dimensions space with colour and shape

6.1.5 Communication Package

This package supports the dynamic data transaction between user interface, process and database in the Web client system. Figure 6-6 illustrates the dynamic data transaction process in the Web client system. Users request an energy/environment analysis to the Web service system through the Web–based interface (i.e. Java-enabled Web browsers). The Web server passes the request to EnTrak components via SQL client and analysis tools. An analysis component corresponding to the request issues a data query to the EnTrak database server using the SQL client component. The data-set extracted from the EnTrak database server is used to make an outcome of the analysis.

This outcome is stored as a graphic image or an object containing a data aspect model and then transferred to a volatile Web page placed in the Web server system. Once the volatile Web page has been updated with a new outcome, the Web page is downloaded to the Web clients. In the case of the image file, it is just displayed within the Web browsers. In the case of the object, the Web clients manipulate it to display the outcome in various user interfaces such as interactive graphics, tables and so on.

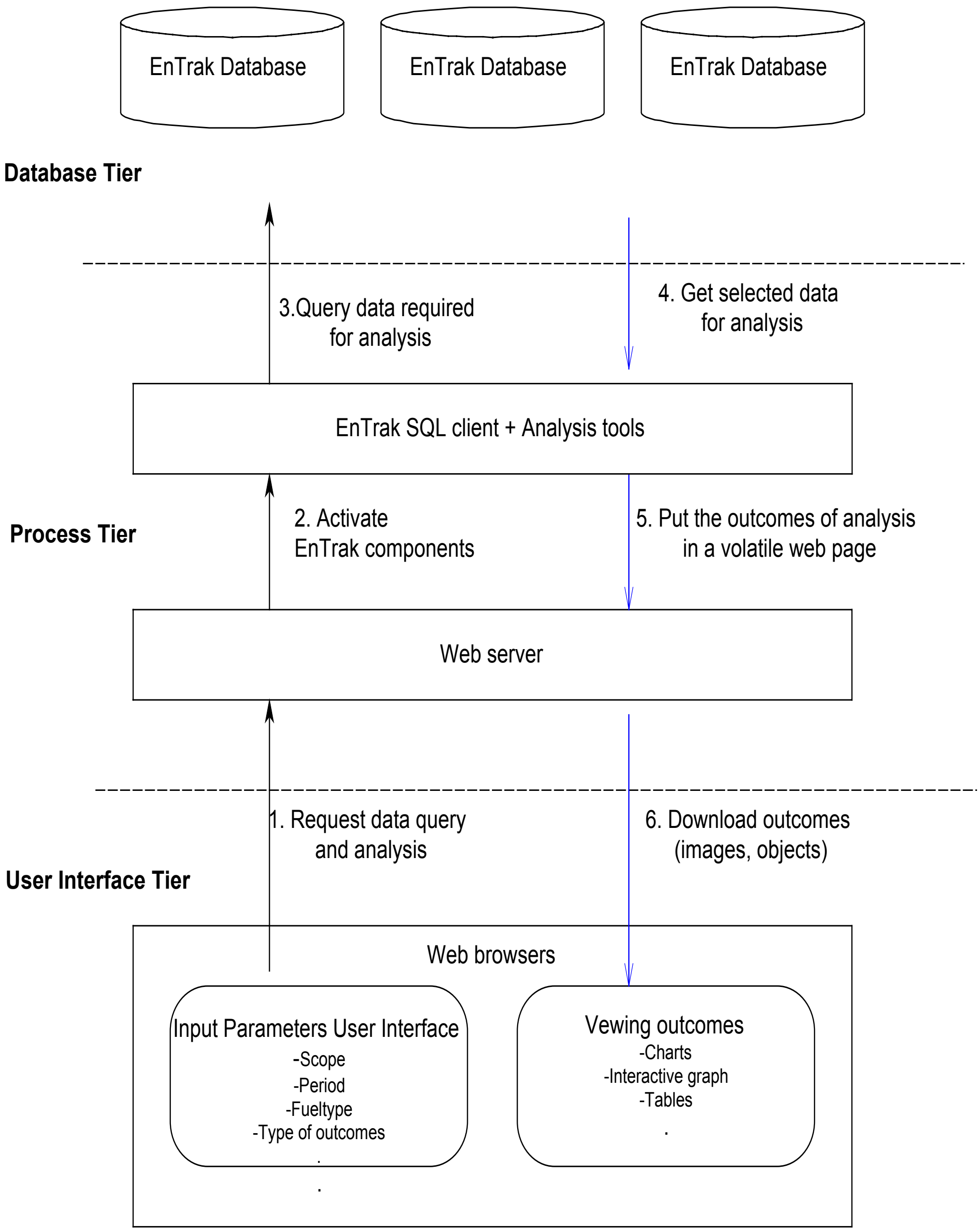

Figure 6-6 Dynamic data transaction process between the Web service system and EnTrak system.

ImageCreator API and ObjectReadWrite API are used in this data transaction process. ImageCreator API is a servlet that generates images in volatile Web pages. For example, when a Web client requests a graphic chart of a monthly energy profile, the graphic chart produced through the profile manager is stored in a buffer memory and then transferred to the corresponding Web page by this API. The ObjectReadWrite API serialises an object and reads/writes it through an HTTP connection. Serialising an object means writing the values of all its data fields into a stream of bytes. Once an object is turned into a stream, it can be written to a file or sent down a communication socket to another system on the Internet (Sun Microsystem 2002). Using the ObjectReadWrite API, the outcome created by an analysis component according to a Web client's request is serialised and sent to the Web clients. Applets in the Web clients use the serialised object at the client-side to display the outcomes in a multi-media enabled user interface.

6.2 Stand-alone Application System

The stand-alone version of EnTrak is a Java application program that contains a set of functionalities, including a SQL database front-end, software integration with third party packages, analysis tools and scope maps. The system is installed and maintained at the user-side. This section describes the structure and components of the system and the basic operation process model.

6.2.1 System Structure and Components

The stand-alone EnTrak application comprises a front-end project manager and back-end resources including modelling applications and supporting documentation (see Figure 6-7). The project manager is a user interface that provides users with an integrated management environment for back-end resources.

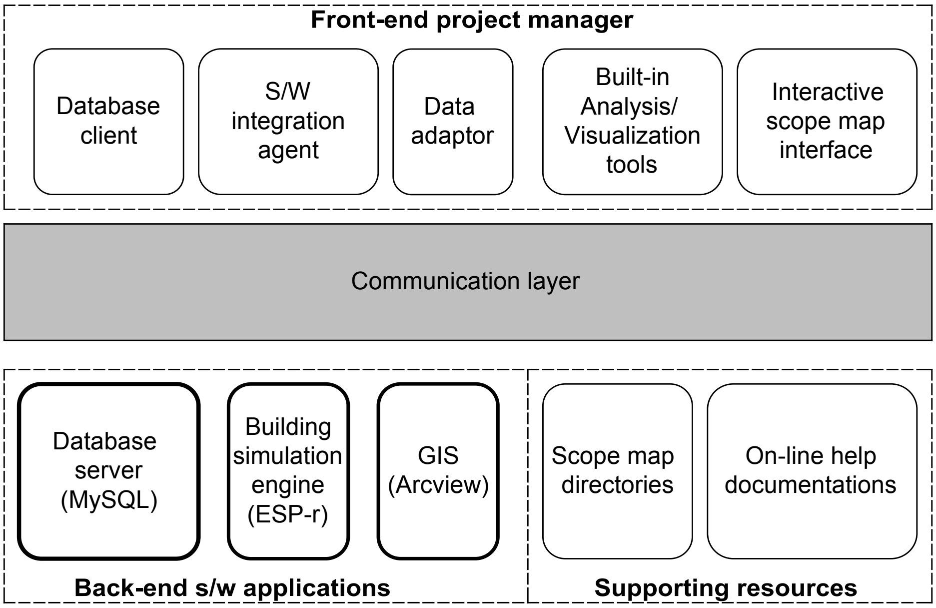

Figure 6-7 The structure of the stand-alone EnTrak system.

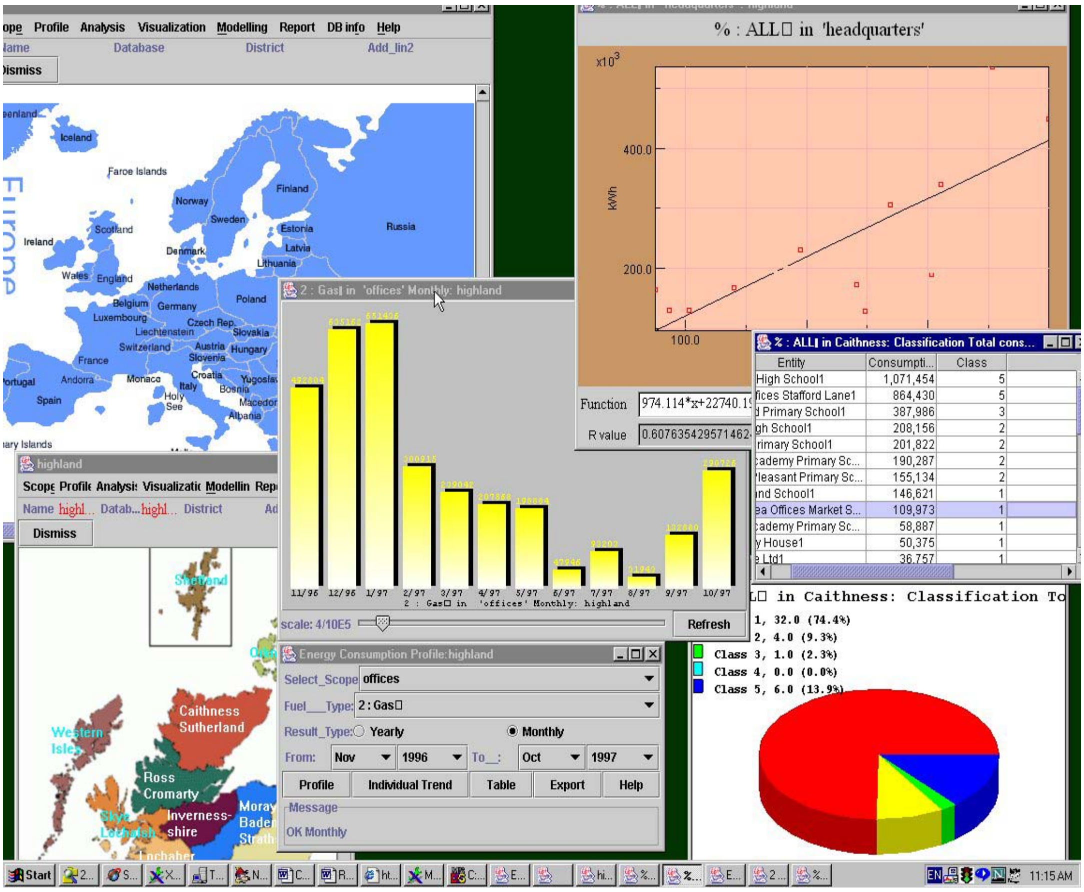

Figure 6-8 A screen shot of the front-end project manager of EnTrak

These resources include SQL engines, third party software packages (e.g. ESP-r and Arcview-GIS), and supporting documentation resources such as map directories, on-line help etc. The communication between the front-end project manager and back-end resources is established within a stand-alone computer or a TCP/IP-based network. Figure 6-8 shows a screen shot of the project manager as a client-based user interface, which has the following components.

- Database client: This is a GUI to access and to update the data of SQL engines in the back-end. It offers efficient tools to browse the data records and to select the data-set within a defined scope.
- Software integration agent: The mechanism of invoking the third party software packages and communicating with them is established in the project manager environment. This makes it possible to construct a seamless integrated system. The integration agent administers the mechanism.
- Data adaptor: This manages data transformation when importing data from external data sources to the SQL database, or when exporting data from the SQL database to analysis tools.
- Built-in analysis tools: Within EnTrak these can be realised with either built-in modules or third party software packages. The project manager has built-in analysis/visualisation modules such as profile, regression, CUSUM, classification, gas emission, 3D visualisation etc.
- Interactive scope map interface: The interactive map interface reads HTML-based image maps by referring to the URL. This creates a graphic front-end for the SQL server, which allows users to select a scope by a simple mouse operation.

In principle, any vendor's SQL engine can be used as long as it has a JDBC driver. In the EnTrak system, MySQL was adopted as the SQL engine (MySQL AB 2001). MySQL is a client/server implementation that consists of a server daemon 'mysqld' and many different client programs and libraries. As it is a multi-user, multi-threaded SQL database server, it meets the need of the EEIS database system.

As a GIS software package offering facilities to visualise, explore, query and analyse data spatially, as well as possessing the ODBC facility, 'Arcview' (ESRI 2003) was adopted to implement the database connectivity and the interoperability of the EEIS for commissioning GIS-base energy/environment data visualisation. This commercial GIS package has a project file that stores configuration parameters, including the data source of ODBC and map themes. By running the project file in a command line environment, the registered data sources are retrieved to make map views automatically when invoked by the stand-alone EnTrak. The Java Runtime API is simply used to manage the command line execution with the complete path name of the executing program and the complete path name of the project file as shown in the following example code.

```
for MS window:
  Runtime.getRuntime().exec( "c:/ESRI/arcview   c:/GIS/springburn.apr" );
for Unix or Linux
  Runtime.getRuntime().exec( "/usr/local/ESRI/arcview   /home/GIS/springburn.apr");
```

HTML-based scope maps presenting the geographical map or abstract image representing the scope of an entity's data are stored in the scope maps directory. The HTML-based image maps are customisable resources that end-users can create and install in a local user directory or remote hosts that users can access. Supporting documentation contains on-line help, tutorials etc. Like the HTML-based map directory, this documentation can be located in a network host and can be accessed with HTTP.

6.2.2 Basic Operation Process

The stand-alone EnTrak application is launched by issuing the following command.

OS_Prompt>java EntrakMain -parameter 'value'

Parameters:

-d database name

-m URL of map directory

-l URL of help

-h Host IP of SQL engine(default: ‘localhost’)

-u username (option)

-p password (option)

-r JDBC driver (default: ‘org.gjt.mm.mysql.Driver’)

-s SQL engine name(default:’mysql’)

Example:

OS_Prompt>java EntrakMain -m file:///d:\entrak\entrak_java\maps\europe\europe.html -l http://103.129.2.32/entrak/help/ -d springburn

The session starts by connecting to a database. In order to establish this connection, the configuration of the connection must be valid, and user authentication must be established. On system start up, the user is presented with a login menu. To protect data resources in the database, user authorisation is managed discriminately. There are two types of operating sessions according to a user’s authority level: end-user session and administrator session. In the end-user session, users get access to the database to query data and request analysis requests. Since the users for a front-end session only have authority for access to the database, they are not allowed to update the database. On the contrary, the administrator can update data or set up the system configuration. User registration for end-users and administrators is therefore required by the SQL server prior to running EnTrak.

Figure 6.9 illustrates the process of an end-user session. Once the connection to the database server has been established, users must select a scope for an analysis or report.

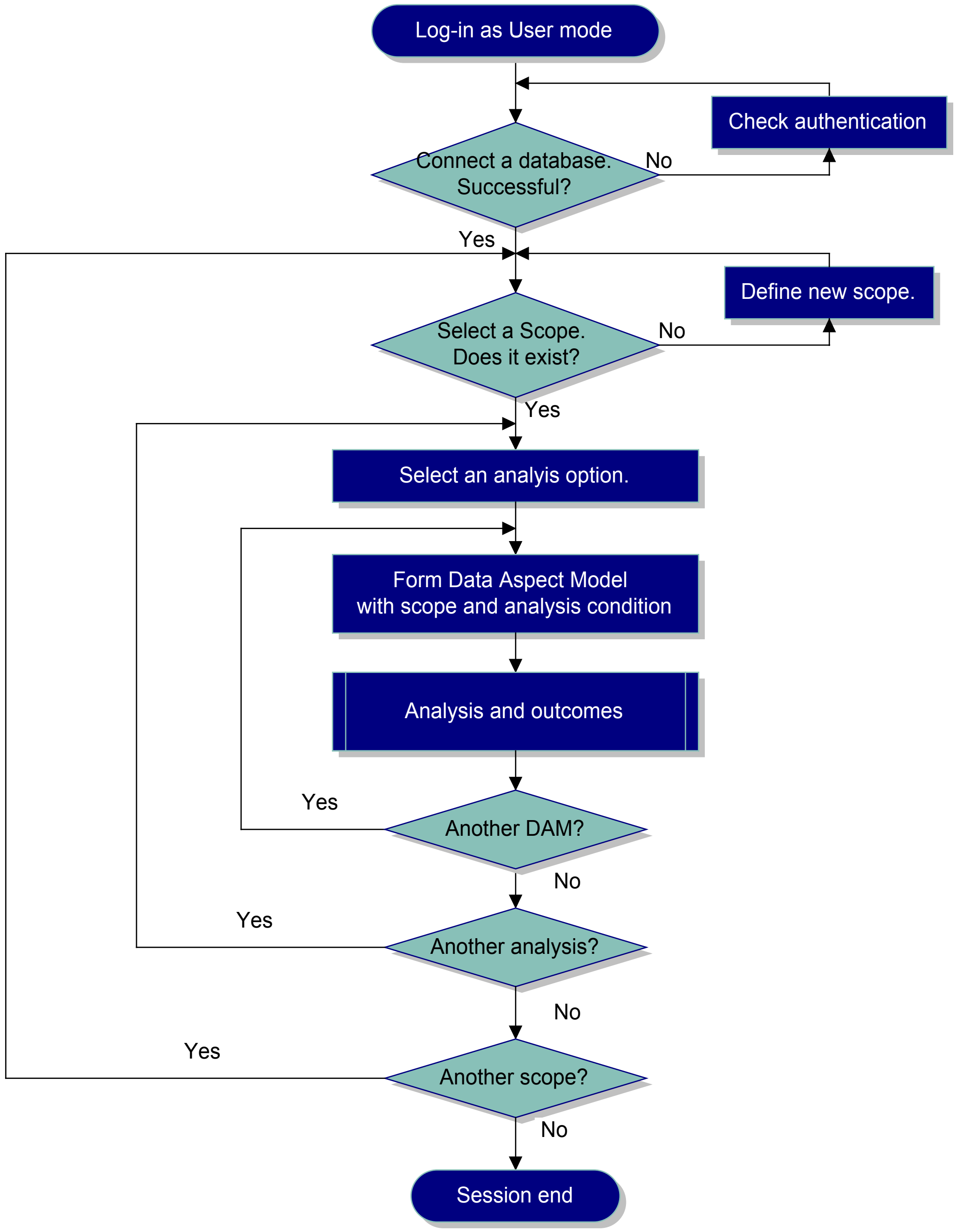

Figure 6-9 Flow chart of the process of an end-user session.

A ‘scope’ may define a set of buildings in a particular region, a group of entities of a given type or any other arbitrary mix. If the scope is not defined in advance, the process of scope definition must be undertaken before proceeding to the next step. An analysis option is chosen within the focus of the selected scope before defining condition parameters (e.g. period, frequency etc) for the analysis. A SQL statement to request data to the database server is executed to form the data aspect table for the analysis. The SQL statement is made by combining the selected scope and the condition parameters. The data aspect table obtained from the database server is passed to the analysis process. The data aspect table can also be exploited to create various types of result views. The tools available in end-user mode such as profile, gas emission, regression/CUSUM, classification, and visualisation have their own manager to make results as required.

Whereas the front-end session is a user-oriented operation, the back-end session is more associated with system servers. Figure 6-10 shows the basic process of the back-end session. Before starting a back-end session, pre-processing for data transformation is required because data input channels are various, and the types of data format are different. For example, virtual data created by simulation modelling, or real data read from meters (sensors) automatically in real-time, may be transmitted to the EnTrak database via a communication protocol. Data collected from other organisation’s databases may be imported through intermediate files.

Even though the data input channels are diverse, the data format must be tailored to a form compliant with the SQL protocol. Since the back-end process is associated with database management, it is important to ensure data security. To this end, the users (usually system administrators) of a back-end session must have permission to add/delete data. Data validity is checked to prevent invalid data from entering into the database.

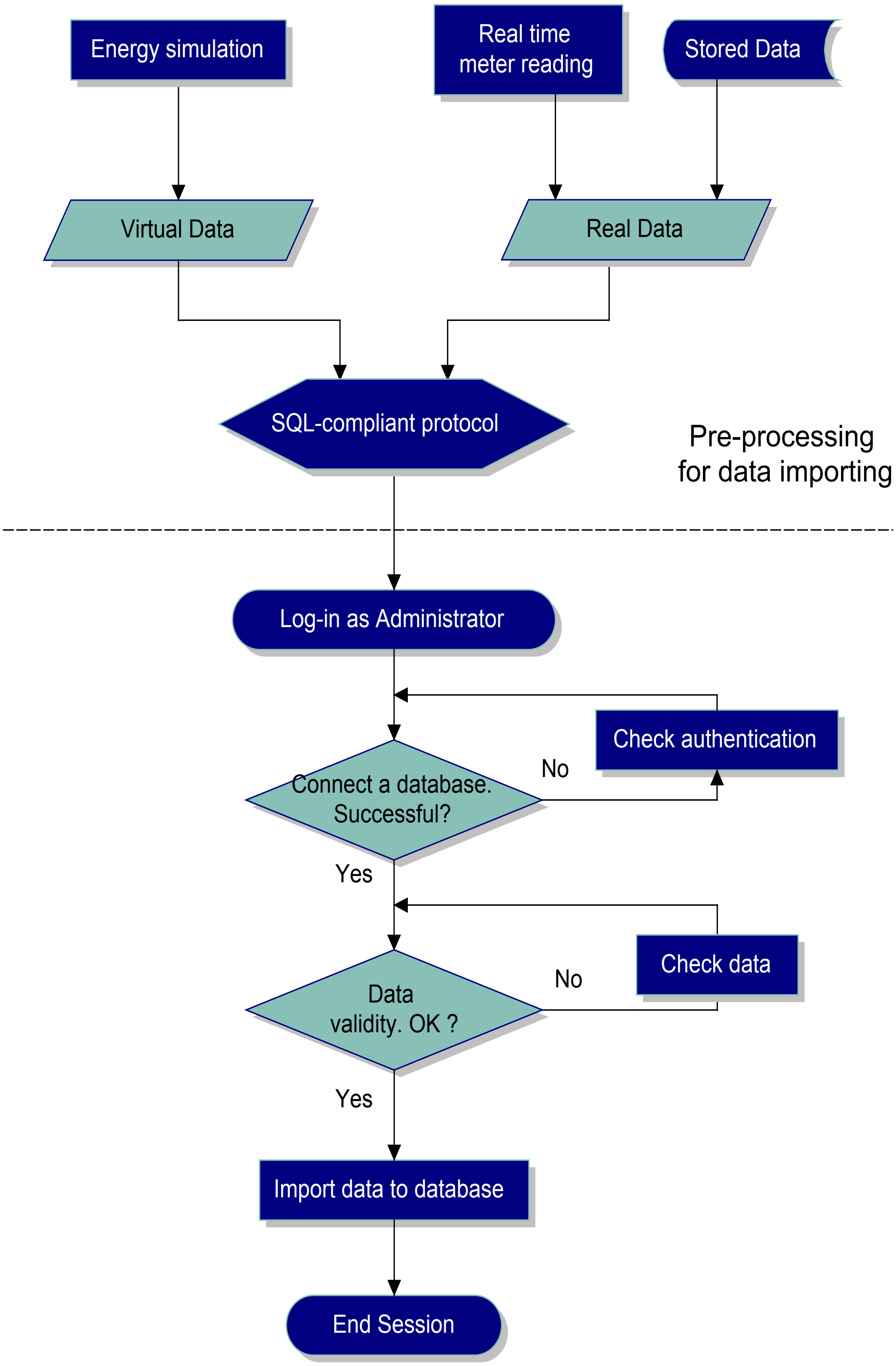

Figure 6-10 Flow chart of the process of a back-end session.

6.3 Web-based Application Supporting Citizen Involvement

Due to the three tiers architecture of EnTrak, the database manager independently acts as a data provider for the Web-client system. The Web-client user interfaces have no burden for the administration of the database system and data collection, while the EnTrak database is the data resource for various Web services each with a different style and purpose (e.g. an individual home energy and environment service or region/institution energy management). Although the functionality of the energy information services can vary, the data source for the information will usually be the same database.

To assess the applicability of the Web-client EnTrak, a prototype of a Web-based service for residential energy users was designed to support citizen involvement in energy actions. Employing the electronic gateway-based monitoring/control system described in Section 5.3 and the Web-based data transaction model, the functional specification of the Web-based residential energy service is discussed in this section.

The Web service starts with user authentication as shown in Figure 6-11. It is essential to make the Web interface secure because individualised data (e.g. energy use, occupancy) is confidential. Accordingly, individual customers have a personalised Web site through which they can access their own data and the aggregated data from the EnTrak database that is not specific to them.

Figure 6-12 shows a personalised Web page for residential customers. The user's identification information includes reference ID, address and log-on time; these data are displayed throughout the session as a banner.

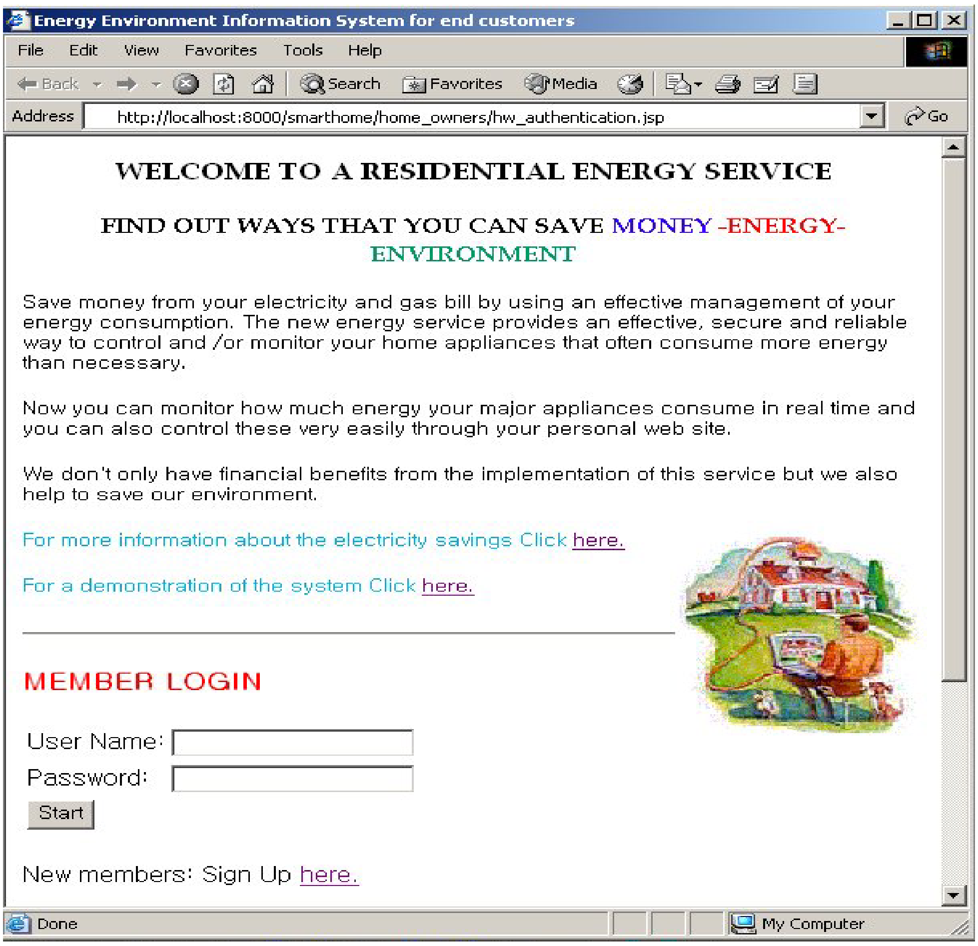

Figure 6-11 The initial section: log-in.

The personalised Web interface not only delivers the information (i.e. monitored data, customised report, advice etc) to the registered user but also provides control functions for home appliance and heating/cooling systems. While the monitoring/control devices are managed via the e-service system, relevant information is conveyed to users via the Web site of Figure 6-12.

First of all, the monitoring section exists to report on the monitored data relating to energy use, cost (breakdown, comparison) and environmental conditions (indoor and outdoor).

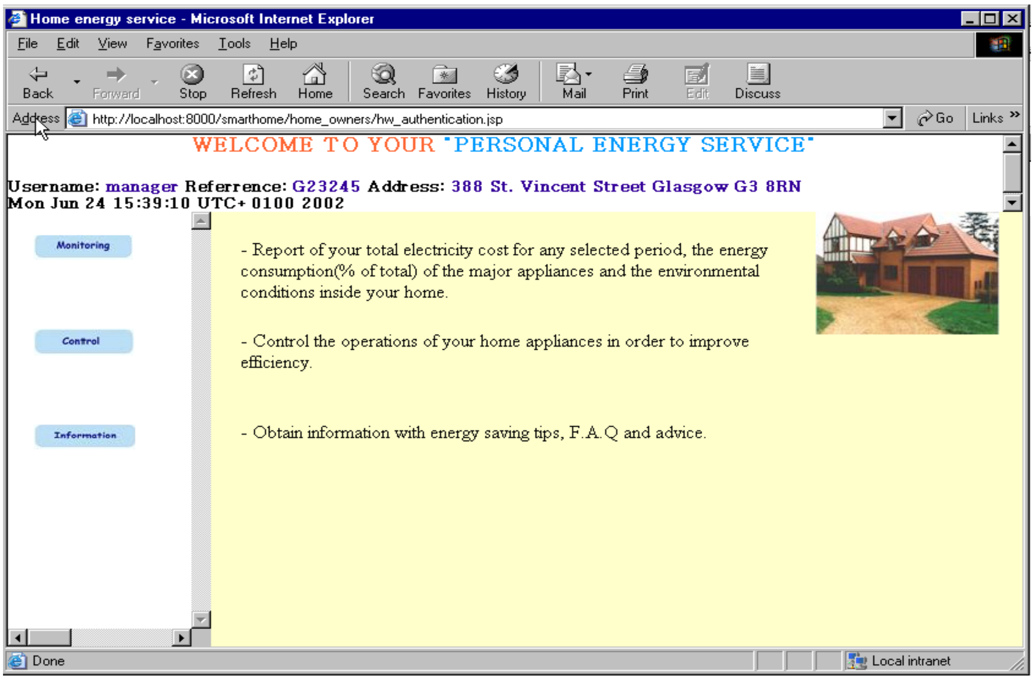

Figure 6-12 The main section.

As shown in Figure 6-13, the user can select the period of the monitored data, the graph type according to frequency (i.e. hourly, daily and monthly) and the monitored item. Historical profiles help users to appreciate long-term trends and compare the change over time.

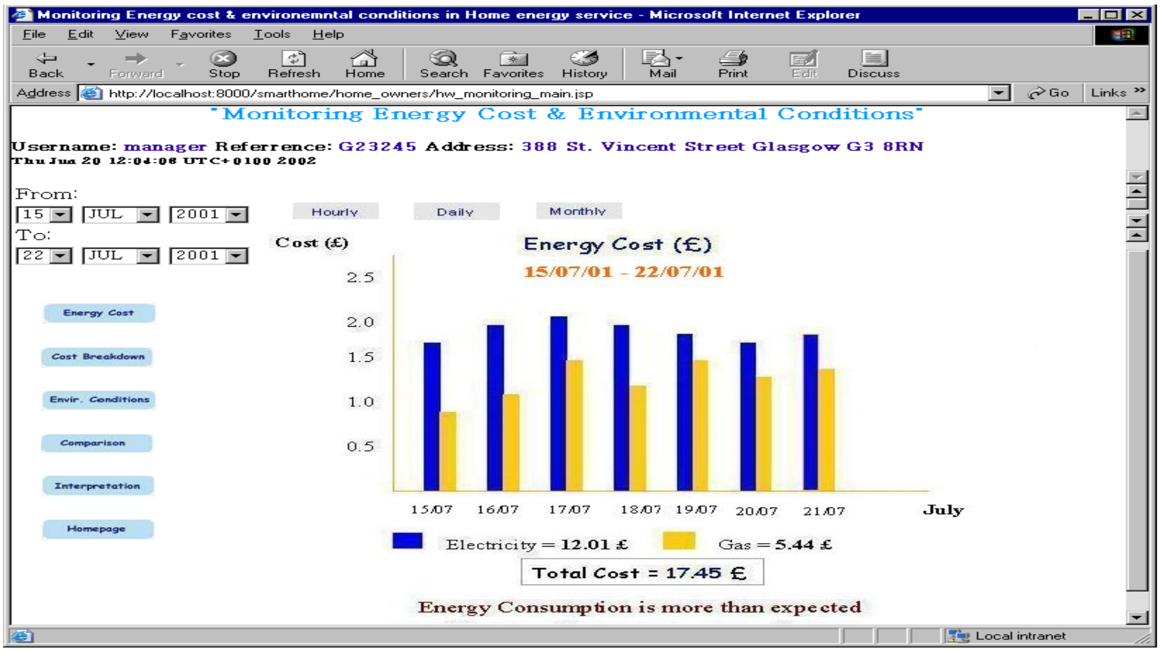

Figure 6-13 The energy profile section.

Real-time monitoring gives the user a report on the current status. Figure 6-14 shows the real-time monitoring of the indoor environment. Temperature and humidity data monitored within each room are displayed in colours with meaningful information associated with occupants' health and safety (red: dangerous, yellow: risk to health, green: safe). This real-time monitoring service can issue alert messages (e.g. e-mail, SMS) according to the data values to prevent energy over-use or alleviate health risk.

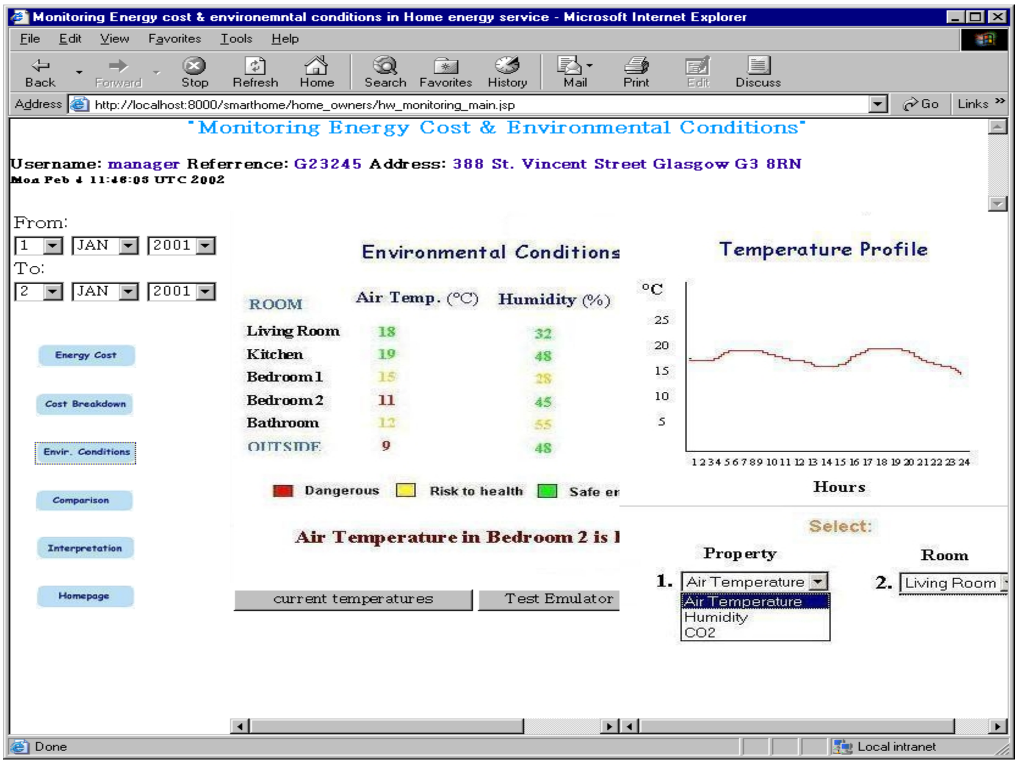

Figure 6-14The temperature profile section.

The alerts can be sent to relevant authorities (e.g. emergency services) as well as occupants. This real time monitoring/alert system will improve the capability of detecting problems and reacting to them in a timely manner.

The comparison profile provides a comparison between a user's own energy use and that of a similar group. The monitored data comes from not only a user's own home but also from other users in the community, which are stored and managed in the EnTrak database. When the comparison profile is made, the data from these other homes is aggregated so that their identification is hidden.

The aggregated data is used to establish a benchmark against which the user's energy use may be judged (see Figure 6-15). This benchmark is intended to give rise to user motivation to reduce energy use.

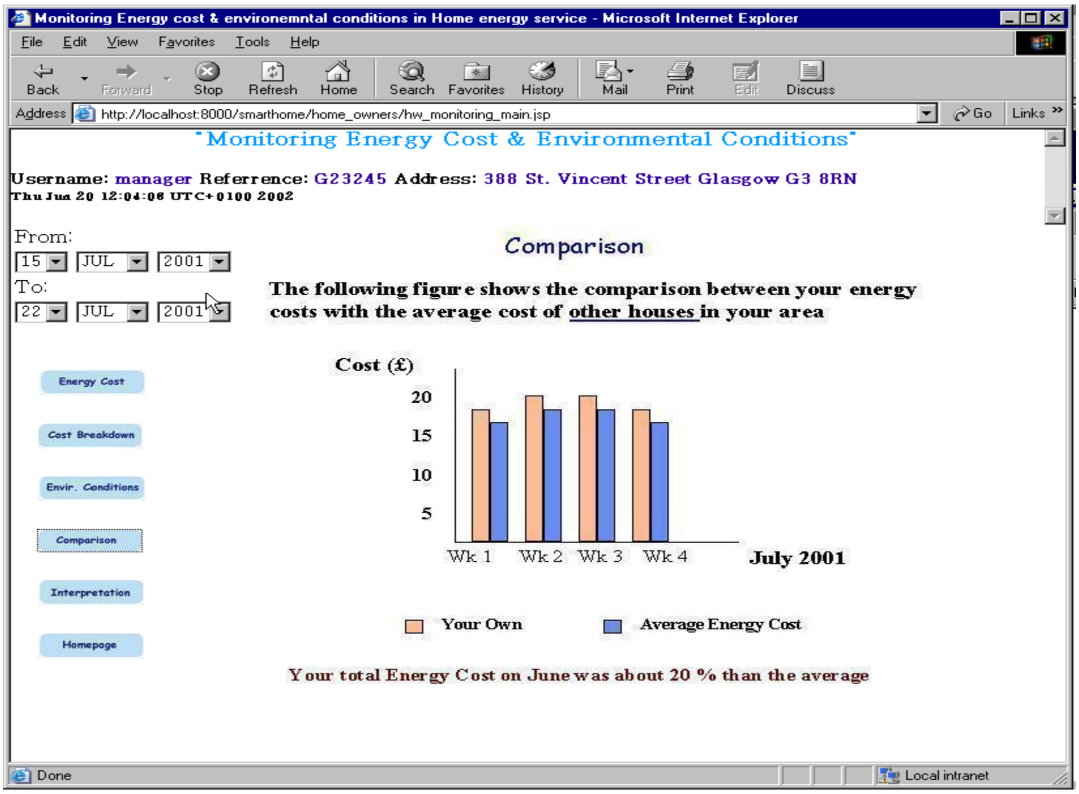

Figure 6-15 The energy comparison section.

Secondly, the control section is designed to provide home-owners with control measures that allows them to be proactively involved in energy saving schemes. As simple application of this control system, home appliances, for example, could be controlled remotely through this Web service. Coupled with the real-time monitoring, the remote control service may enable prompt user action in response to problematic incidents. In addition, the control section could have an advanced control scheme such as the sharing of control intervention with utilities. This means that utilities can take control of appliances in individual homes that may have a suitable contract. Users give control access permission to a utility while, in return, they receive a financial benefit through a reduced tariff. Then, the utility can manage their peak load by adjusting the home electricity load within a reasonable range. For instance, the set-point temperature of heating/cooling systems within contracted customers' homes may be adjusted down to reduce the peak loads. Such dynamic control could be achieved by the e-service system via the dynamic Web interface. One such interface for control is shown in Figure 6-16.

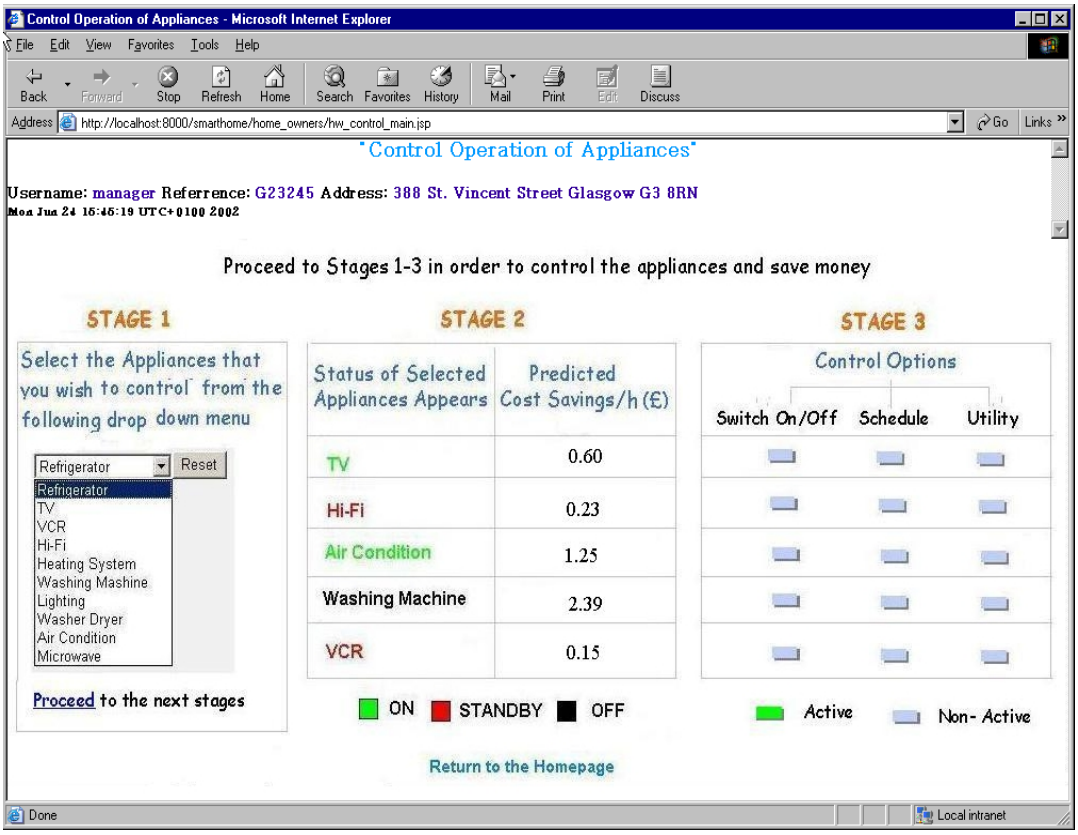

Figure 6-16The appliance control section.

This offers information on the current status of appliances and the options for control (i.e. switch on/off by user, scheduled program, utility control). The user selects the appliances to control at Stage 1, while the status of the selected appliances are displayed at Stage 2. The status is distinguished by the colour according to the electrical power status (i.e. on, standby, off). The cost savings are predicted on the basis of the financial benefits that the utility may offer when the utility control option is selected.

Finally, the information section offers additional text-based energy information to users and links to energy-related information sources. Such sources could include regulations, energy saving advice, technical reports etc. In addition, customers can share their knowledge and discuss issues within an on-line forum. Figure 6-17 shows a Web page providing such a forum.

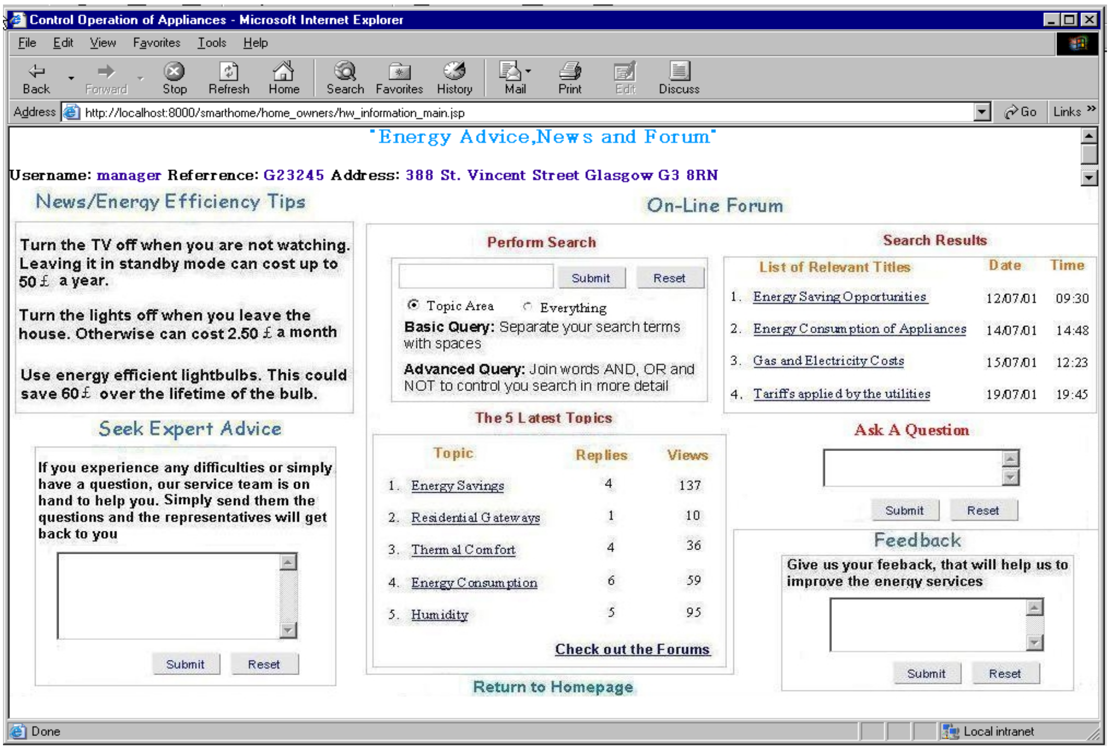

Figure 6-17 Information section.

The main aims of the information section are to achieve:

- An electronic resources circulation system whereby information (e.g. newsletters on energy efficiency, software applications for energy audit etc) can be transferred to the Web site and circulated to members in real-time.
- Online information services and support. A 'question and answer' forum on energy efficient technologies or available financial support can be accommodated as part of the Web site. The contents are stored and retrieved by people who have shared problems. Since the forum can be dynamically updated, a so-called dynamic knowledge-base can be maintained.

- o Formulating, preserving and retrieving work procedures. Formulised documentation (e.g. annual HECA reports) can be automatically generated. The Web site provides a location where the documentation can be archived for future reference and updated as lessons are learned.

Such a Web-based system requires more secured devices as the energy information must be kept confidential. A prototype of the Web-based information sharing system was implemented for supporting secured e-resources management. Appendix F describes the system structure and operating mechanism.

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Chapter 7 Case Studies

The purpose of these case studies is to demonstrate the applicability of the EnTrak system in support of

- o the evaluation of properties' energy use and a strategic approach to energy management at the regional scale;
- o municipal energy action plan formulation and new types of citizen involvement; and
- o energy management within institutions.

The following section describes case studies relating to three different scales in order to demonstrate EnTrak applicability under different data scope scenarios. The practical issues in handling different data quality and resolution are discussed along with the role and relevance of modelling.

7.1 Regional Scale: The Highland Council

7.1.1 Context

The Highland Council, which covers an area of 25,000 km^2, is the largest region within the European Union. The population density is low at 8 person/km^2 (c.f. the average for Scotland at 66 persons/km^2). There are 8 districts within the region (see Figure 7-1). The Council supplies a range of services including education, libraries, social services and health services. The energy service department is responsible for maintaining and operating the properties used to support the above provisions. There are 1,344 properties corresponding to 1,811 energy accounts consisting of 2,936 energy meters.

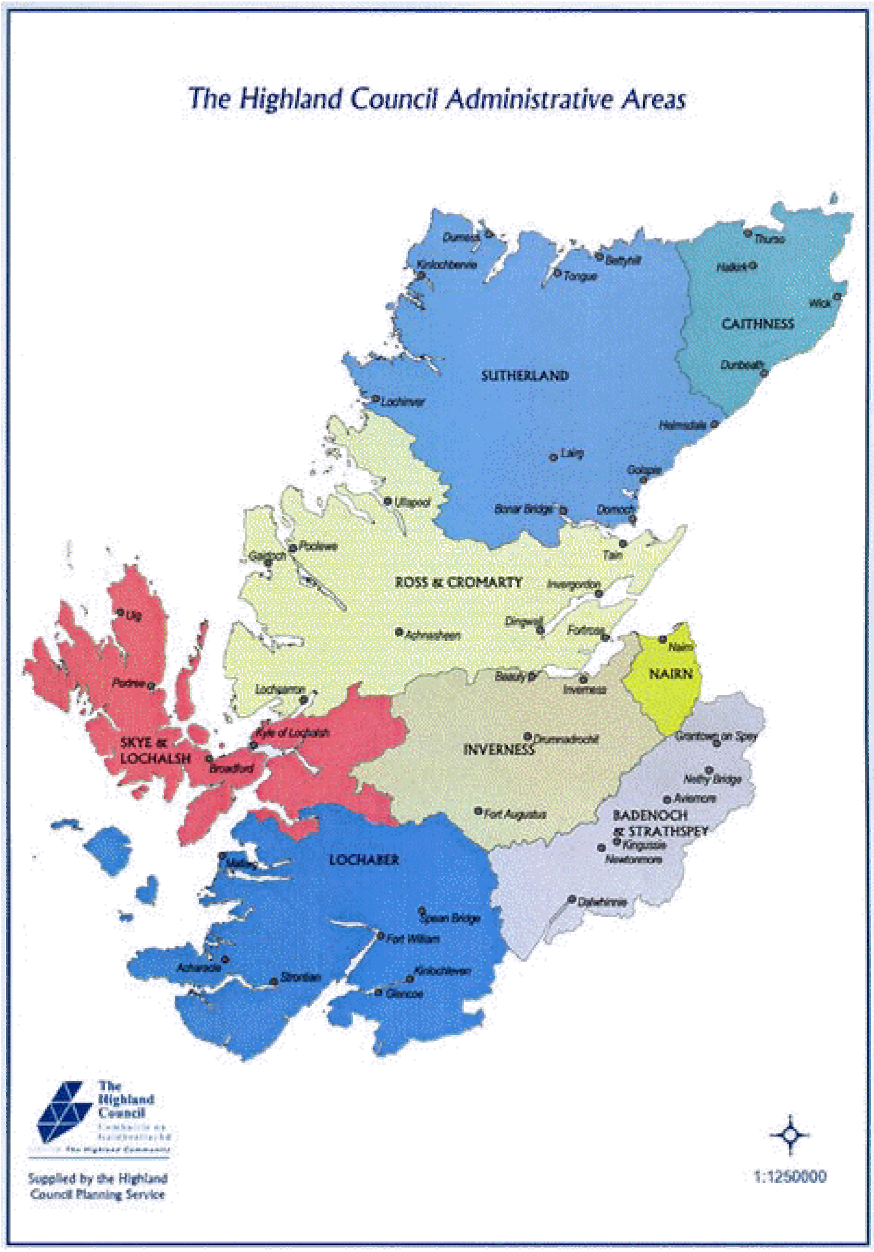
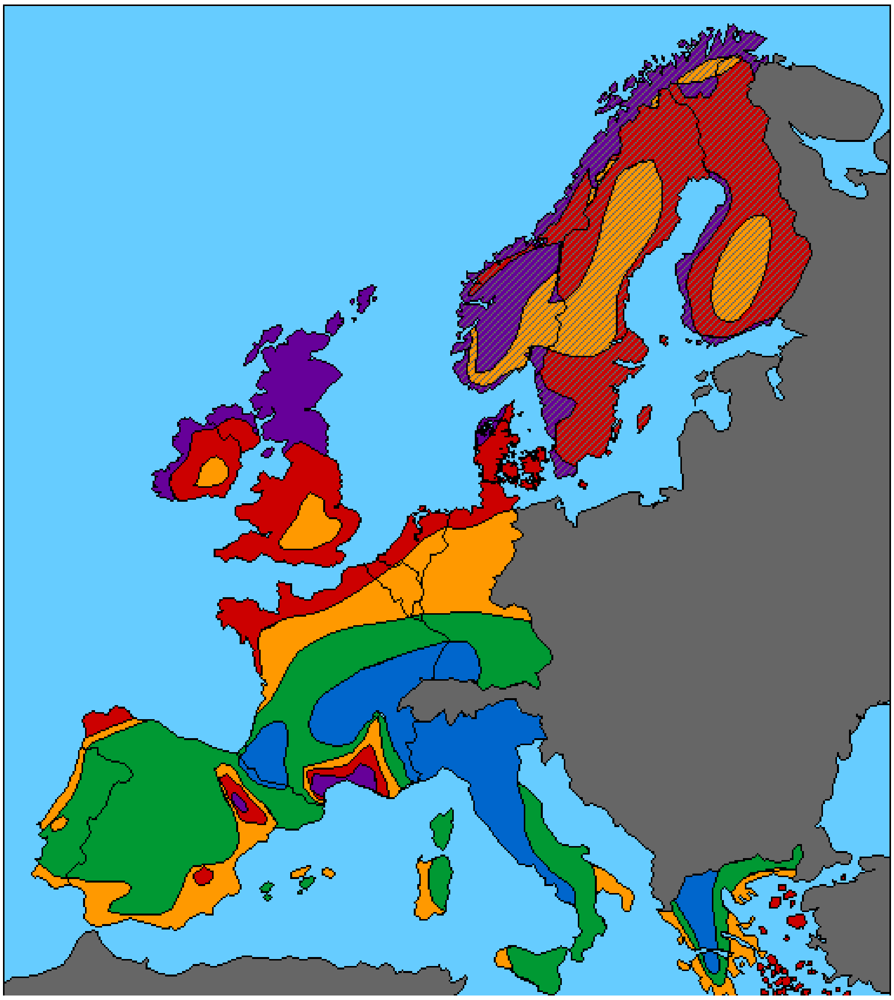


Figure 7-1 Highland Region.

Since a diverse range of fuels is consumed over a large spread of properties (e.g. burning oil, coal, electricity, gas, kerosene, LPG, petrol etc), fuels are purchased from a number of suppliers. This requires a number of import formats to handle these data electronically. Due to the absence of common data connectivity, a large portion of data must be entered manually based on utilities' bills. Considering the amount of properties, manual data input imposes a major load on staffs, resulting in incomplete and incorrect data.

Since energy consumption is associated with various factors, total consumption is not a reliable input to energy action planning. Rather, it is assumed that the patterns of energy consumption better reflects the required energy action. That is, it is necessary to identify the energy consumption patterns in order to determine the best strategic approach to energy saving. However, due to the size of the region, the large number of properties and poor data availability, it is not trivial to determine the overall energy performance of properties distributed geographically and to recognise distinctive patterns according to each property type.

As well as the identification of energy patterns, it is significant to adopt alternative energy systems in terms of energy strategy because the region possesses huge potential for renewable energy resources utilisation. In fact, Highland Region is one of the most favourable areas for wind power in Europe. Figure 7-2 illustrates the wind resources at 50m above ground level for five different topographic conditions: 1) sheltered terrain, 2) open plain, 3) coastal, 4) open sea and 5) hills and ridges. Therefore, it is worthwhile investigating the feasibility of wind farms in the region. Such a feasibility analysis was implemented using 5 virtual wind farm entities as described in this case study.



	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²
	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400
			>7.5							
			5.5-7.5							
			<5.5							

Figure 7-2 European wind resource (Troen and Petersen 1989).

7.1.2 Establishing the Database and Configuring the Analysis Model

1,344 Council properties were registered in the EnTrak database as administrated by the Council's Energy Service Department. There are 79 types of entities defined in the building table (see Appendix C for the code list defined for the EnTrak database). About 30% (470 entities) of the registered entities belong to the Education Department of which the majority are schools (nursery, primary and secondary). Table 7-1 gives the departmental breakdown.

Table 7-1Statistics of entities belonging to departments.

Department	*Count*	*Percentage*
Accommodation	41	2.54
Housing	59	3.66
Community Education	4	0.25
Education	470	29.13
ocial Services	98	6.07
Transport Services	150	9.30
Cultural Services	104	6.35
Chief Executive	14	0.87
Law & Administration	4	0.25
Personnel Services	6	0.37
Finance	1	0.06
Planning	3	0.19
Property Services	8	0.50
Protective Services	81	5.21
Childrens Reporter	1	0.06
Police	122	7.56
Fire	40	2.48
Economic Development	4	0.25
Registrar	1	0.06
Etc	402	5.02
Total	1613	100

Although the energy data input from the utility bills covers the period from 1980 to 2002, not all entities have energy data for the entire period. This is because

- o manual input is carried out inconsistently and intermittently; and
- o some properties were sold/bought by the Council or newly built/demolished during the period.

While the energy data are dealt with by the energy service department, property information such as land use, environmental factors and political-economical data is managed by other departments. However, as the IT Department of the Council administers the information resources electronically using a database program, relevant information for the EnTrak database was easy to obtain through internal database connectivity (i.e. ODBC). For example, the GIS co-ordinates (i.e. 'Gis_xref' and 'Gis_yref' in the entity table) of properties and their architectural specification (i.e. area, volume etc) from the property database were imported to EnTrak's building table. The SQL statements used for data preparation are given in Appendix B.4.

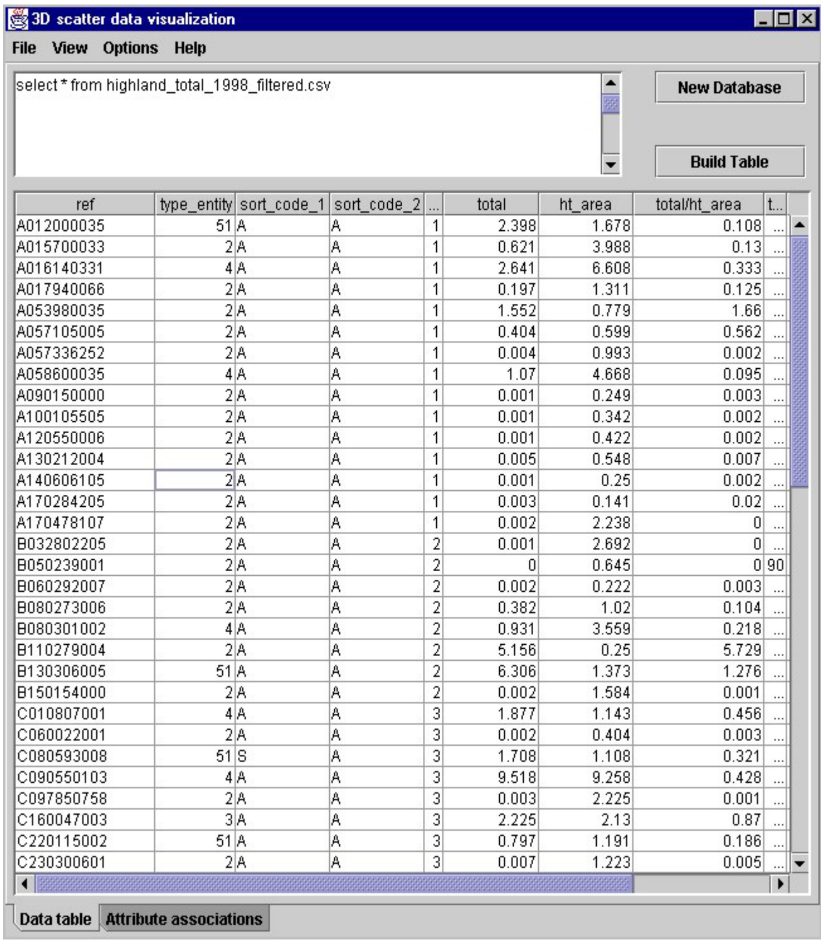
In order to implement the feasibility test concerning renewable energy systems deployment, the GIS information related to environment, policy and technical aspects (e.g. locality, bird populations and grid access respectively) were employed from the Planning Department's database for this case study. The Planning Department already held such information obtained through an EC research project (Clarke 1966) on the potential for wind power development in Caithness. Supply-side virtual entities for wind turbine farms in Caithness were created and imported into the EnTrak database with basic information (e.g. geographic location and identifiers). Table 7.2 illustrates the list of the virtual entities inserted into the entity table. 'SV' is the identifier for a Supply Virtual entity while 'WINDT' corresponds to wind turbines.

Table 7-2 List of the Supply Virtual entities for the wind power feasibility test.

Ref	*Data_type*	*Entity_type*	*District*	*Gis_xref*	*Gis_yref*
Bardnaheigh	SV	WINDT	CA	302794	966082
Durran Mains	SV	WINDT	CA	318604	962509
Spittal Hill	SV	WINDT	CA	318062	956553
Hill of Clayton	SV	WINDT	CA	333438	963591
Scoolary	SV	WINDT	CA	329215	969005

To create a 3D data visualisation model, total energy consumption, heating area and energy consumption per heating area were selected corresponding to the x, y and z axes respectively of the graph. A set of data for the model (i.e. DAT) was selected from the EnTrak database focusing on the properties of the Education Department. Data from this department were used because the properties constitute a large portion of the Council's estate, and the data of these properties are relatively well prepared.

The selected data had to be filtered to ensure validity since there were still error data and partly missing items in a data record. After the filtering process, the data were converted to meet the scale of the 3D data visualisation model as described in Section 4.4. The re-scaling of 'total', 'ht_area' and 'total/ht_area' was implemented on the basis of the 10:10:10 scale mapping of xyz co-ordination. Figure 7-3 shows the converted DAT.



ref	type_entity	sort_code_1	sort_code_2	...	total	ht_area	total/ht_area	t...
A012000035	51	A	A	1	2.398	1.678	0.108	...
A015700033	2	A	A	1	0.621	3.988	0.13	...
A016140331	4	A	A	1	2.641	6.608	0.333	...
A017940066	2	A	A	1	0.197	1.311	0.125	...
A053980035	2	A	A	1	1.552	0.779	1.66	...
A057105005	2	A	A	1	0.404	0.599	0.562	...
A057336252	2	A	A	1	0.004	0.993	0.002	...
A058600035	4	A	A	1	1.07	4.668	0.095	...
A090150000	2	A	A	1	0.001	0.249	0.003	...
A100105505	2	A	A	1	0.001	0.342	0.002	...
A120550006	2	A	A	1	0.001	0.422	0.002	...
A130212004	2	A	A	1	0.005	0.548	0.007	...
A140606105	2	A	A	1	0.001	0.25	0.002	...
A170284205	2	A	A	1	0.003	0.141	0.02	...
A170478107	2	A	A	1	0.002	2.238	0	...
B032802205	2	A	A	2	0.001	2.692	0	...
B050239001	2	A	A	2	0	0.645	0	90
B060292007	2	A	A	2	0.002	0.222	0.003	...
B080273006	2	A	A	2	0.382	1.02	0.104	...
B080301002	4	A	A	2	0.931	3.559	0.218	...
B110279004	2	A	A	2	5.156	0.25	5.729	...
B130306005	51	A	A	2	6.306	1.373	1.276	...
B150154000	2	A	A	2	0.002	1.584	0.001	...
C010807001	4	A	A	3	1.877	1.143	0.456	...
C060022001	2	A	A	3	0.002	0.404	0.003	...
C080593008	51	S	A	3	1.708	1.108	0.321	...
C090550103	4	A	A	3	9.518	9.258	0.428	...
C097850758	2	A	A	3	0.003	2.225	0.001	...
C160047003	3	A	A	3	2.225	2.13	0.87	...
C220115002	51	A	A	3	0.797	1.191	0.186	...
C230300601	2	A	A	3	0.007	1.223	0.005	...

Figure 7-3 The DAT for the 3Ddata visualisation model.

The attribution of the points to be plotted in the 3D space was set up by classifying the properties into 4 types: nursery, primary, secondary schools and community centres. As described in Table 7-3, 77 entities among 470 registered with the EnTrak system were chosen after the filtering process for data validity and availability.

Table 7-3 Property data and attribution mapping.

Property type	*Count*	*Color*
Nursery School	1	Blue
Primary School	49	Green
Secondary School	17	Purple
Community Centre	10	Cyan

7.1.3 Outcomes and Applicability

Identifying Energy Performance of Properties

Although the IT Department maintains the information on current properties, GIS information is not available for all properties. The distribution of the Highland Council's properties as registered with EnTrak can be seen in Figure 7-4.

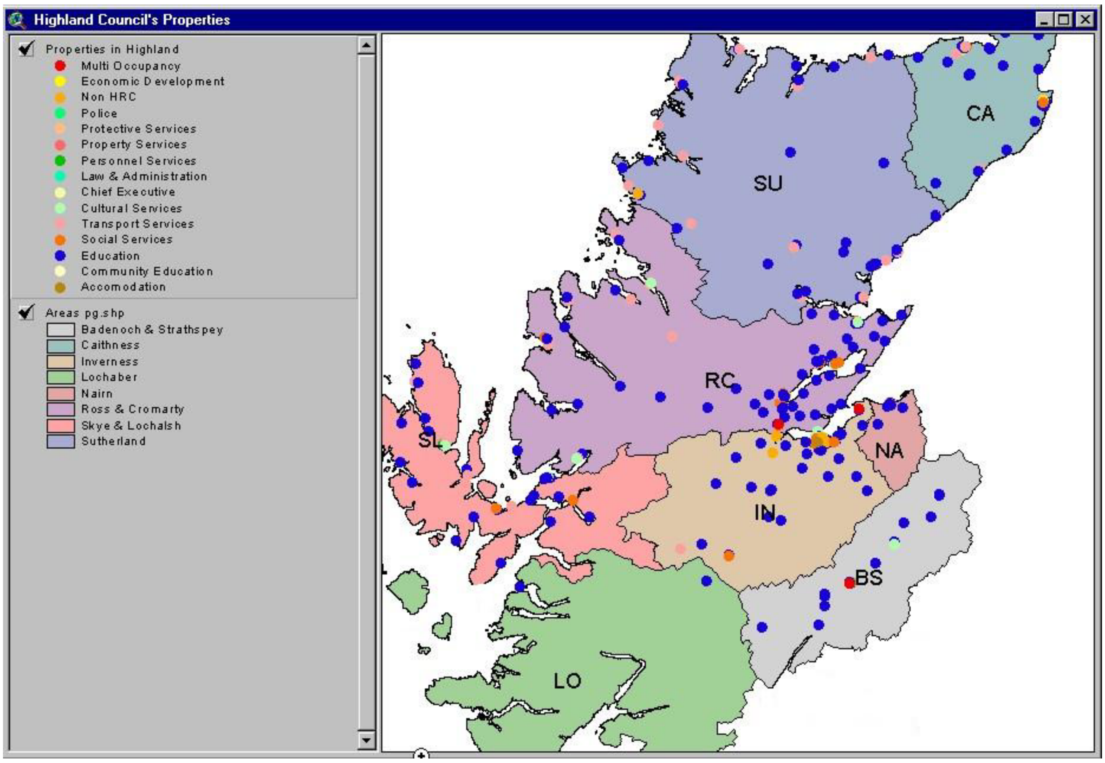


Figure 7-4 Distribution of properties of Highland Council.

Figure 7-5 shows the distribution of energy consumption for education properties within the region. Here, the unit of energy consumption is kWh although the different fuels correspond to different initial units. The total energy consumption was classified into four categories. Green corresponds to low total energy consumption, red to high consumption. The energy map (Figure 7-6) also shows data that has been normalised. Such maps provide the energy manager with information on the geographical location of energy hot spots. Energy managers so alerted can respond immediately.

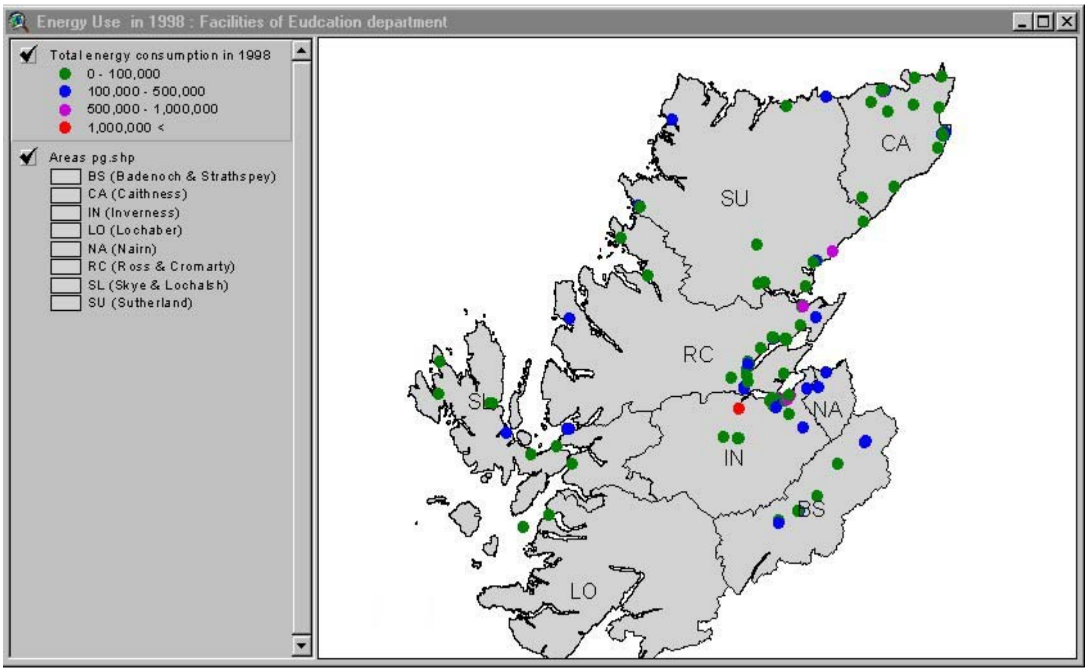


Figure 7-5 Distribution of education properties based on energy use.

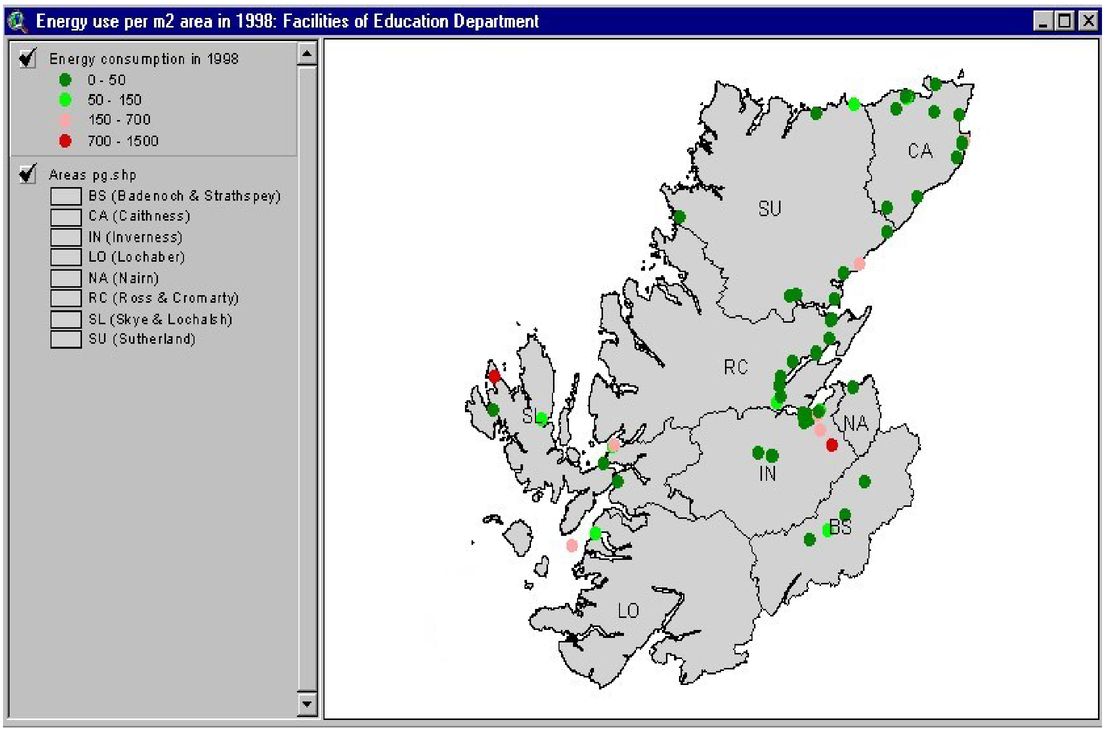


Figure 7-6 Distribution of education properties based on energy use per property floor area.

Often, it is difficult to determine which properties should be targeted to improve energy performance. The energy hot spots on the maps may not be directly related to building energy performance because of other factors such as occupant behaviour. Also, classification of energy consumption has to be varied for each time period because whole properties are affected by common factors such as weather. A comparative analysis based on the same scale would not effectively highlight the difference between properties. In relation to large-scale energy management, GIS-based data views are limited in their ability to identify overall trends.

To address this issue, a 3D data visualisation model of energy consumption has been devised. Figure 7-7 shows an example where the entities (i.e. nursery, primary, secondary and community centre) appear in different patterns according to the entity type. Primary schools (green) and secondary schools (purple) are especially distinctive. This pattern distinction can be seen more clearly in Figure 7-8. A group of entities in a given category has a distinct pattern in the data space every year. Such a pattern is sustained unless the properties are upgraded. It is expected that the overall energy performance of the properties can be assessed by reviewing the energy patterns.

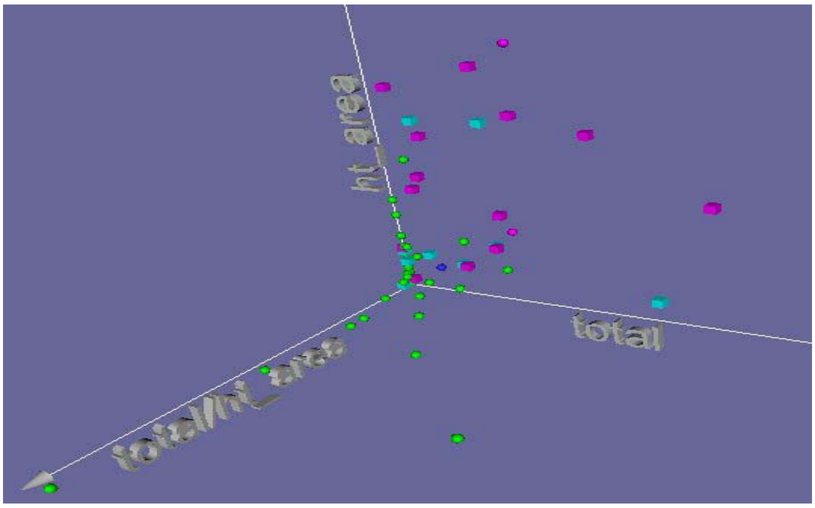


Figure 7-7 Energy patterns of education properties in the 3D data space.

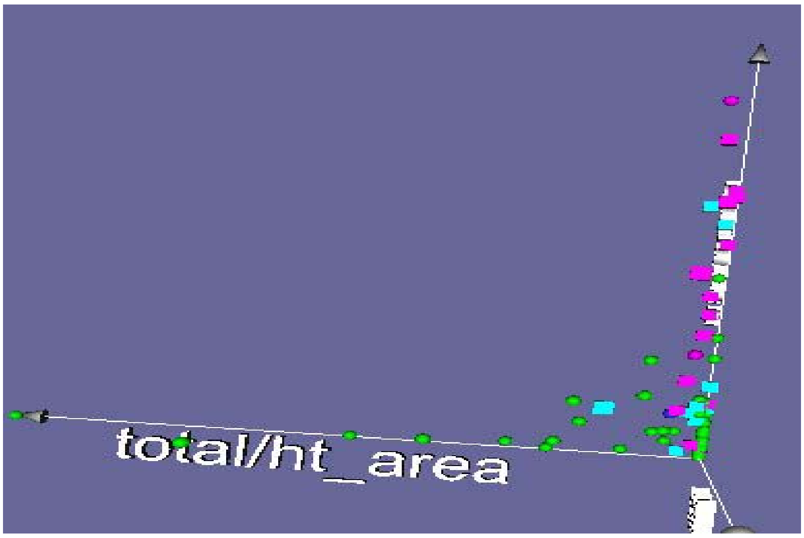


Figure 7-8 Section view of total consumption versus unit consumption.

Feasibility of Wind farms

This feasibility test is a scenario to find out the most favourable sites for prospective wind farms. While there are various factors to be concerned regarding wind farm siting, they are classified into two aspects: environmental possibility and technical feasibility. These aspects were scored according to the planning factors as defined in Appendix G: an overall assessment was then arrived at by aggregating the scores allocated to individual elements and comparing alternative geographic locations. The outcomes of the assessment are illustrated in two map views: technical opportunity and environmental opportunity.

Figure 7-9 is the map view concerning technical opportunity. The technical opportunity is categorised into 5 levels from 'most favourable' to 'likely' to 'most unlikely' according to the calculated score (4-9). Technically favourable areas are easily seen on the map view. Combining technical opportunity with environmental opportunity (Figure 7-10) gives rise to superimposed areas on the map view, from which viable sites for wind farms may be identified. As can be seen in Figure 7-11 only 'Spittal Hill' is an overall acceptable site. This site would be the best candidate for obtaining planning permission.

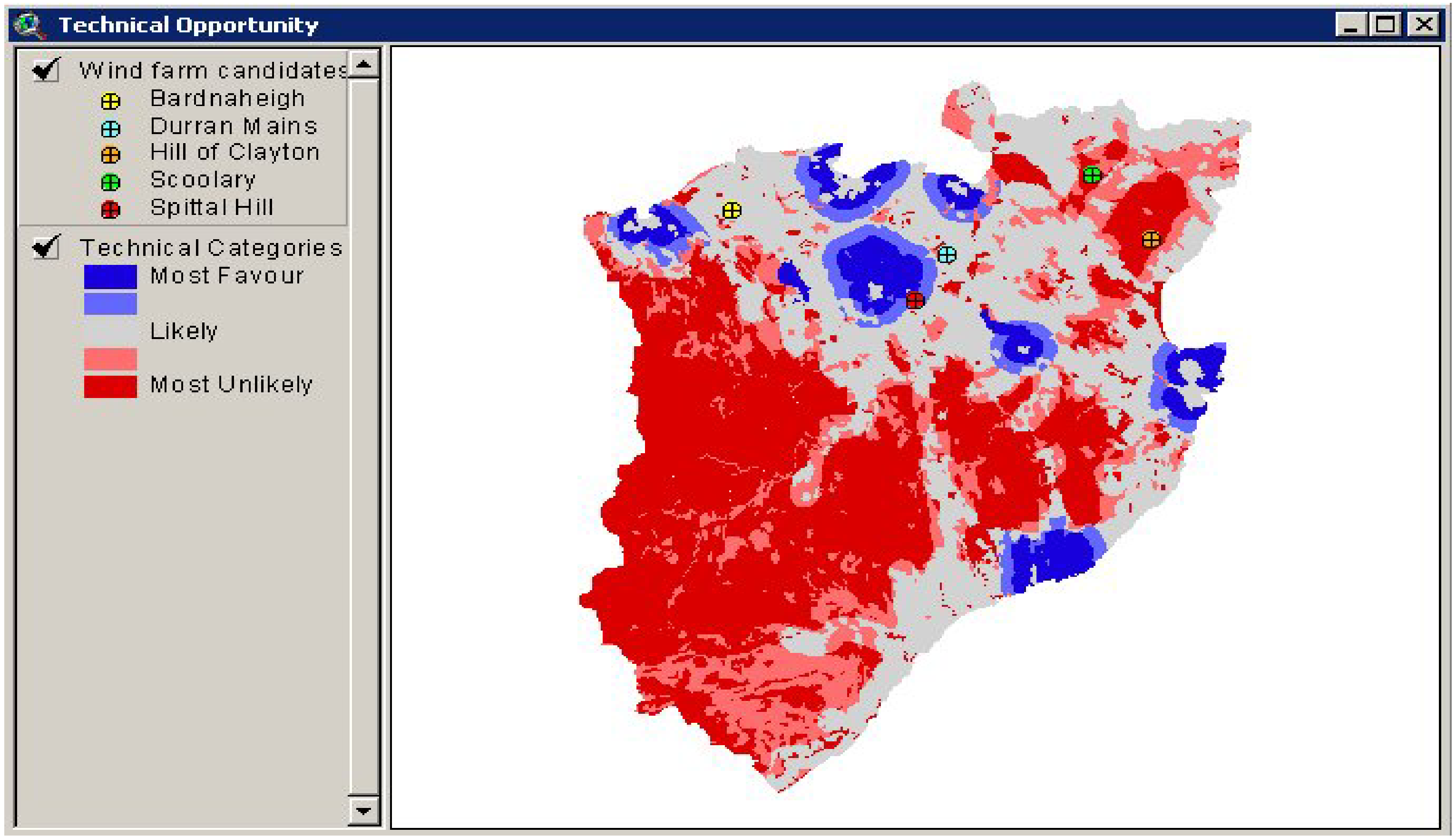


Figure 7-9 A GIS view for identifying technical favour for wind farm sites

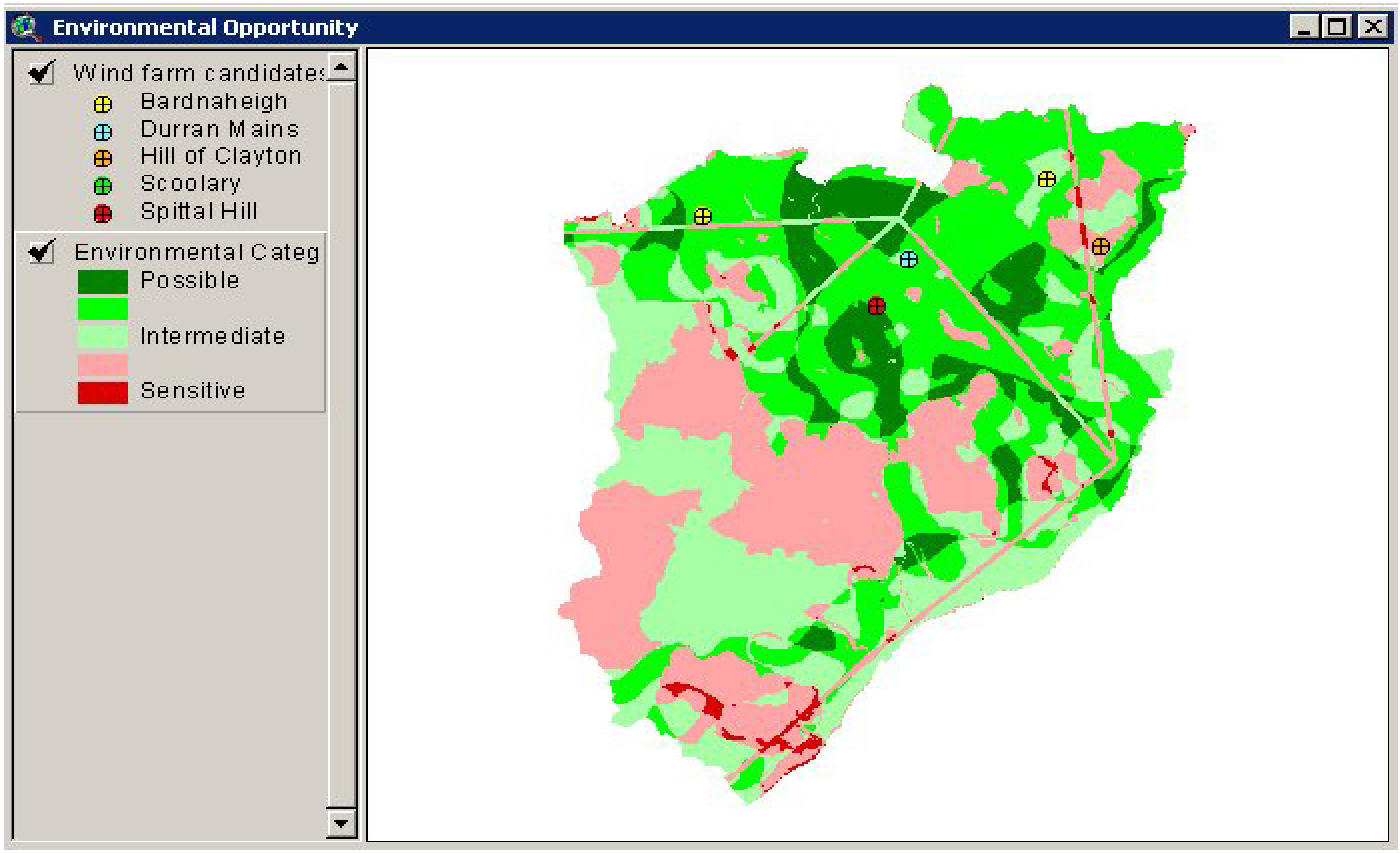


Figure 7-10 A GIS view for identifying environment and policy possibility for wind farm sites.

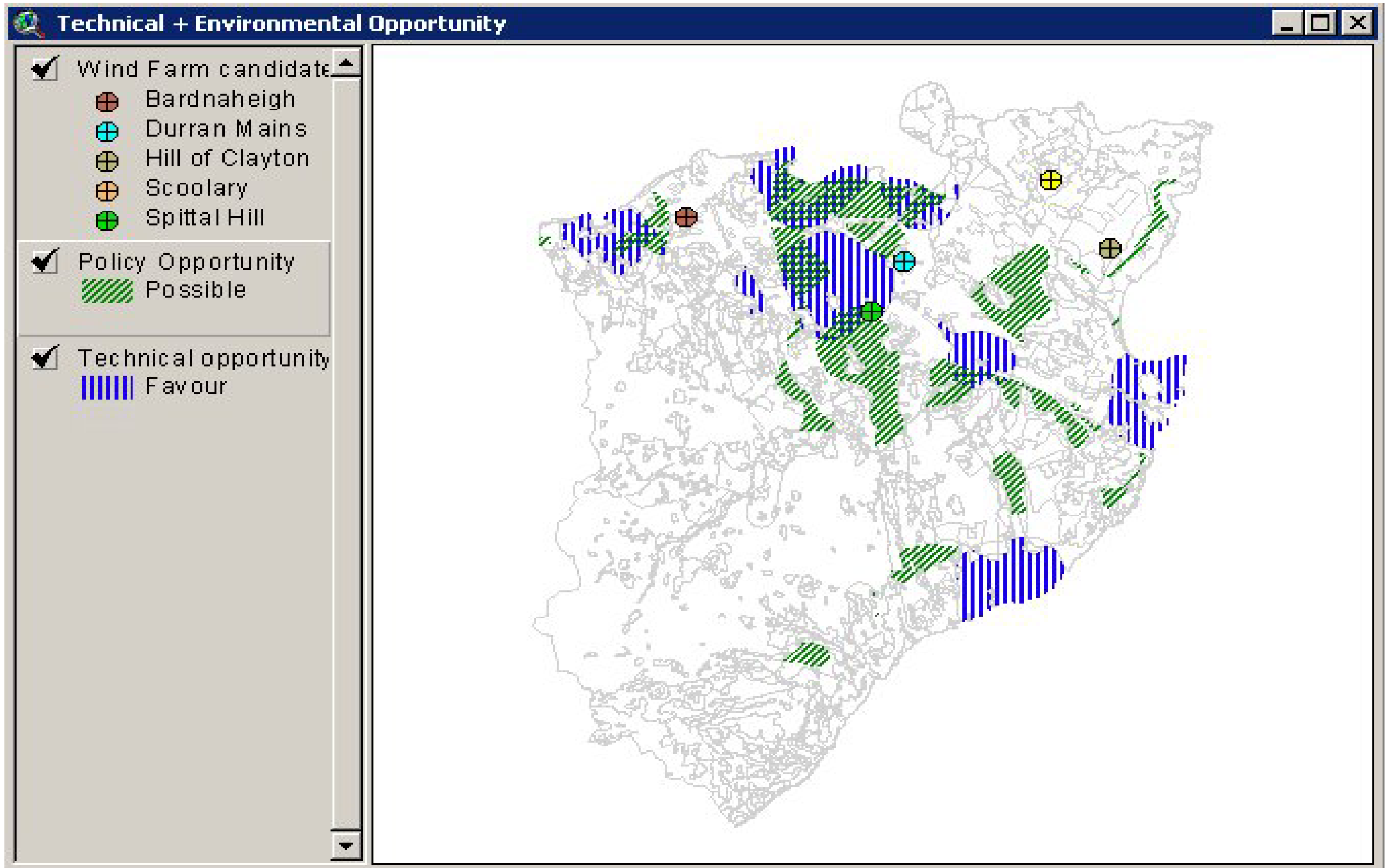


Figure 7-11 A GIS view displaying the opportunities of possible wind farm sites.

7.1.4 Discussion

GIS-based energy maps and 3D data visualisation provide an insight into the energy behaviour at the regional level. The energy maps illustrate the geographic distribution of energy consumption while the 3D plots identify inherent trends. Despite a small data set (77 points), the 3D data visualisation model was able to create informative patterns. It is likely that the distinctiveness of the patterns will be improved if more data points are included.

As the reliability of data visualisation depends on data availability, it is necessary to establish data connectivity with utilities. Although the energy department of the Council can request transaction energy data from utilities in an electronic format, it is non-trivial to implement on-line data because the variety of formats will give rise to a technical barrier. A generic data importing procedure with a unified data format is required, while the SQL-compliant data communication protocol will provide low cost and simple connectivity.

EnTrak can also provide on-line data connectivity for inter-Council's data sharing so that a benchmark analysis can be implemented with other Council's data. By doing this, each Council's energy manager can be informed on the energy performance of properties at any time. Such an inter-connection of local Council databases (e.g. 32 Councils in Scotland) does not need huge investment or additional data procedures other than mutual agreement for database access and common definition of entity types. Even the definition of entity types may not be hard because the properties managed by Councils have little difference in terms of their use (e.g. schools, community centre, public services etc), which can be clearly classified.

Although planning procedure requires various considerations and extensive information, energy managers can be provided with appropriate decision-support on demand by combining in-house information resource (e.g. virtual/real entities, energy data) and external department's information (e.g. landscape, road, environmental policy etc) via the EnTrak analysis facilities. As the internal (i.e. EnTrak) and external (e.g. Planning Department's database) resources are integrated via the Internet, update of information in external resource (e.g. new roads, change of policy) can be easily accommodated an input to the planning process. This gives decision-makers significant advantage in handling strategic approaches as well as routine-based energy management.

7.2 City Scale: Springburn Area, Glasgow City

7.2.1 Context

To evaluate the impact of energy actions and help in the planning of new energy strategies from a city viewpoint, an urban scale energy model is required. This model is used for the identification of energy demand profiles, prediction of the impact of scenarios concerning the adoption of renewable energy sources and so on. In constructing the urban energy model, extensive data are required (e.g. land use, building types, ownership etc), and the capabilities of the model depends on the resolution of the data available. This case study considers how high resolution data may be established, and demonstrates the outcomes of the GIS-based urban energy model.

7.2.2 Establishing the Database and Configuring the Analysis Model

Two wards within Glasgow were selected, Ward 34 and Ward 36, which roughly cover the Springburn area located to the north-east of the city (see Figure 7-12). Most of the buildings in the Springburn area are either commercial or domestic properties. The data on properties were extracted from the City's corporate database where the information is held for use in connection with tax and electoral registers. Each property corresponds to a household, which could be a flat or a detached house.

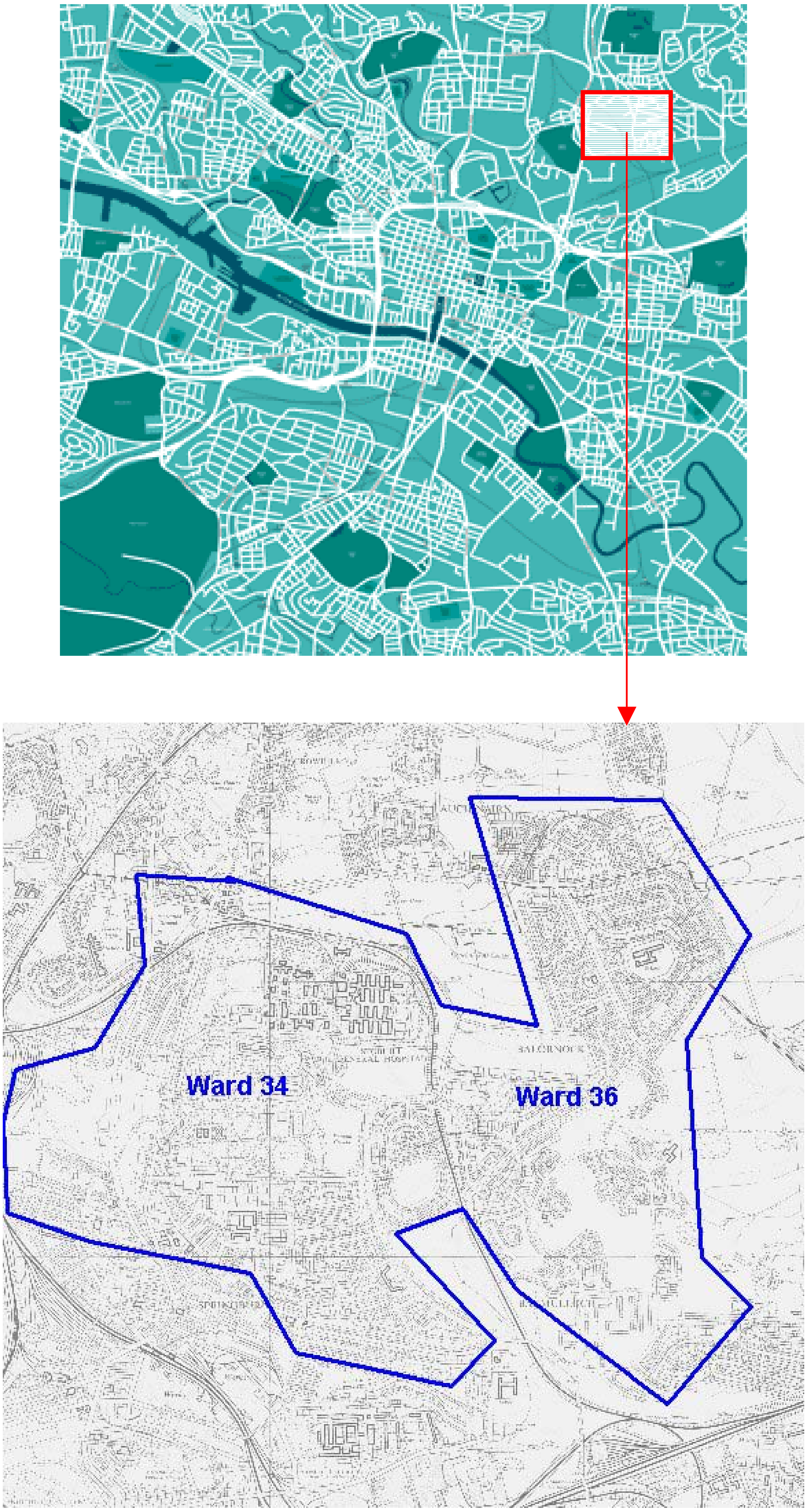


Figure 7-12 Springburn area in Glasgow.

There are 7,311 properties classified into 18 architectural house types (see Table 7-4). Most of these data contain geographical co-ordinates, address, property type, ownership, letting type, house size etc (refer to Appendix C for the list of codes used for this database). As not all data were provided, the remaining properties were left unidentified. The properties were classified according to size as determined from the number of apartments. The majority of properties have 3 or 4 apartments as shown in Table 7-5.

Table 7-4 Statistics of registered properties by architectural house type.

Code	*Property type*	*count*
AG	Aged couple –ground	10
AU	Aged couple –upper	20
DG	Deck access –ground	3
DU	Deck access –upper	401
DV	Detached Villa	1
ET	End terrace 2 storey	205
MT	Mid terrace 2 storey	286
LF	Lower flat	677
UF	Upper flat	721
MM	Multi-storey 1^{st} and above	80
MU	Multi-storey 5^{th} and above	432
SD	Semi-detached	636
TE	Tenement	952
TG	Tenement ground	409
TU	Tenement upper	1042
SS	Sheltered housing	34
NT	Non tenement	1254
LU	Lock up	114

Table 7-5 Statistics of registered properties by house size.

Code	House size (apartments)	Count
1	1	99
2	2	613
3	3	2874
4	4	2960
5	5	288
6	6	24
7	7	9
8	8	4
99	Not available	434

There was difficulty in collecting the energy data due to confidentiality constraints. The local Council has no right of access to data for individual properties in the private sector and only a small part of the estate (less than 1%) is owned by the Council. To overcome the problem, a scrambling mechanism was adopted (Evans 2000). The utility, ScottishPower, supplied electricity consumption for groups of properties (typically 10), but scrambled to prevent the data being associated with a specific household. Likewise, TransCo provided gas consumption data for a similar selection of scrambled properties. This technique permitted adequate database resolution while overcoming issues of data confidentiality.

To assign these scrambled data to a property, a 'prototype' entity was created to hold the scrambled data. This prototype was associated with the average fuel and power consumption. The actual house types in the group were then associated with the prototype entity. In all, 750 prototypes were created and assigned data. By this method, 5,493 of the 7,311 properties were assigned data. The remaining 1,818 are a mixture of undefined, deck access, lock-ups, sheltered housing with non-traditional letting codes or house types.

To create the GIS-based energy model, an area map (1/10,560 scale) was scanned and registered as a layer in EnTrak. This layer shows streets and landmarks in Springburn.

Data tables were then created in the GIS package to link the ‘building’ data table to the ‘energy’ data table within the established Entrak database. The attribution layers are then plotted over the area map referring to the location of all properties. Different energy map views were created using the two layers by selecting focused data items and changing features of their attribution.

7.2.3 Outcomes and Applicability

The properties in the database are presented on GIS-based map views created by EnTrak. The distribution of properties according to property type is shown in Figure 7-13. The colour of the plotted points corresponds to building type, while the shape is associated with the location of individual household in the building. Properties with missing data are plotted in white. Since the GIS co-ordination of properties is allocated at the site level, some properties (e.g. entities located in a high rise building) will have the same co-ordinate so that they will overlap. The information of the overlapped properties on the map view can be obtained by clicking on the point. Likewise, the resolution of the map view is high enough to enable the visual characteristics of the properties to be viewed at district and household levels. The map view also provides the distribution of properties classified by house size.

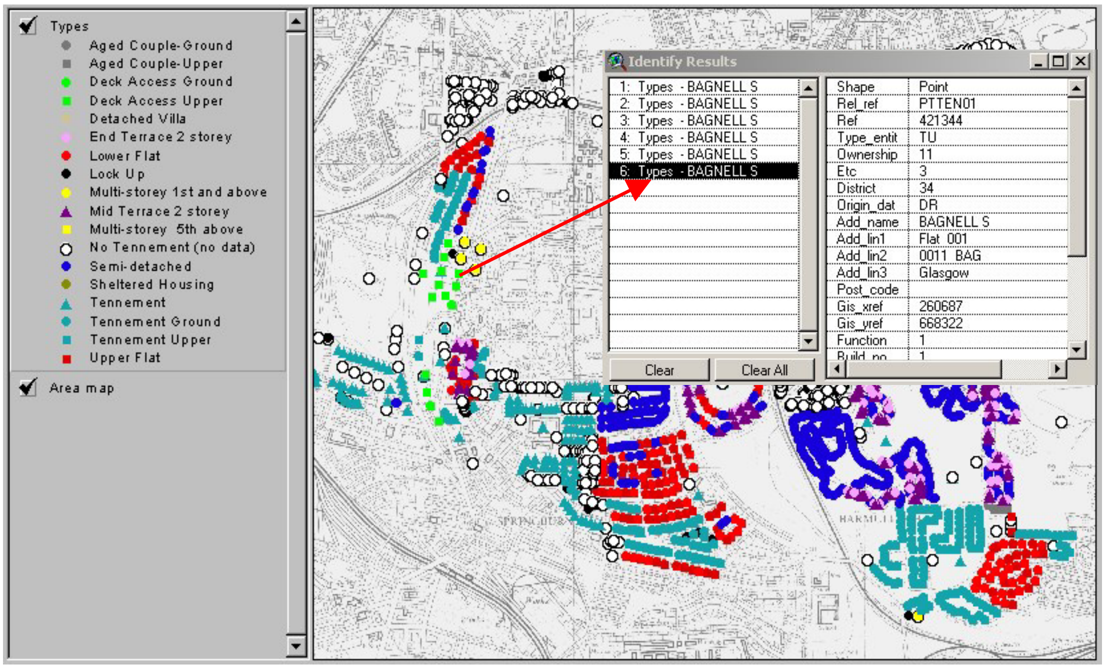


Figure 7-13 Distribution of properties according to property type.

The properties in the area were classified on the basis of their total electricity consumption in 1997. The result is displayed on the energy map view of Figure 7-14. The per-apartment, normalised energy consumption was then calculated to assist with the detection of problematic properties (Figure 7-15). ‘Poor’ or ‘bad’ properties, so-called high energy spots, are then readily recognised on the map view.

Figure 7-14 Energy classification according to energy consumption (yearly total electricity consumption in 1997).

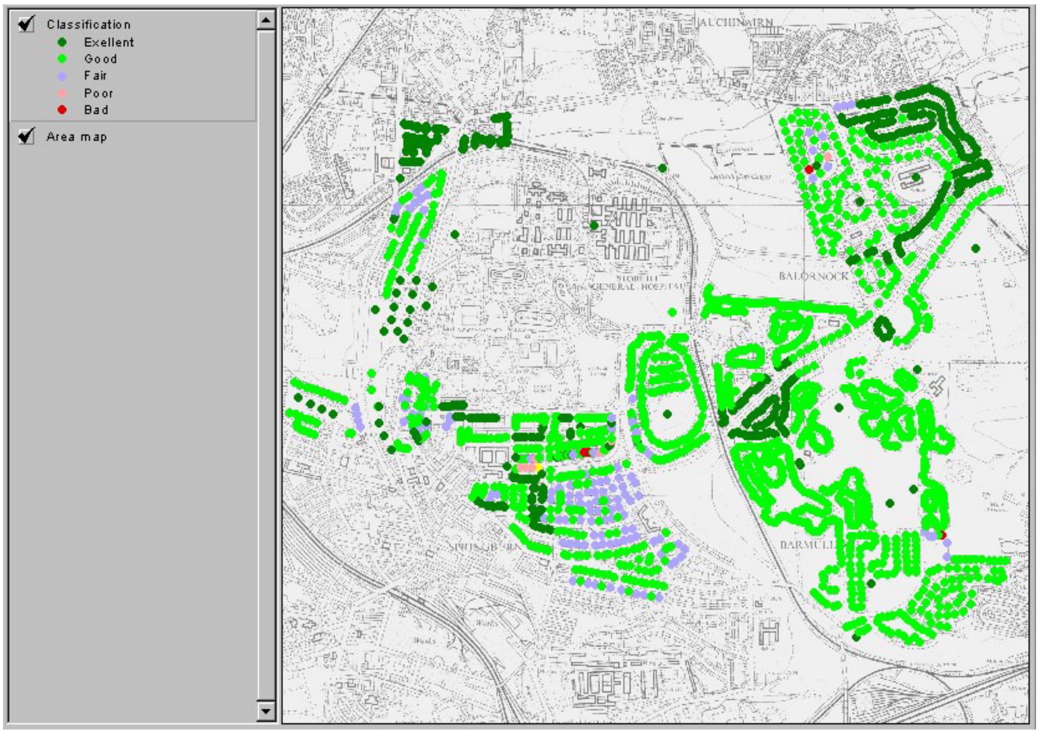


Figure 7-15 Energy classification according to energy consumption per apartment.

Targeted properties according to a given condition is supported (e.g. large properties, > 4 apartment, with high consumption). Figure 7-16 shows the distribution of large properties (blue points in the map view), while Figure 7-17 identifies those properties with electricity consumption of more than 1000 kWh/year (yellow).

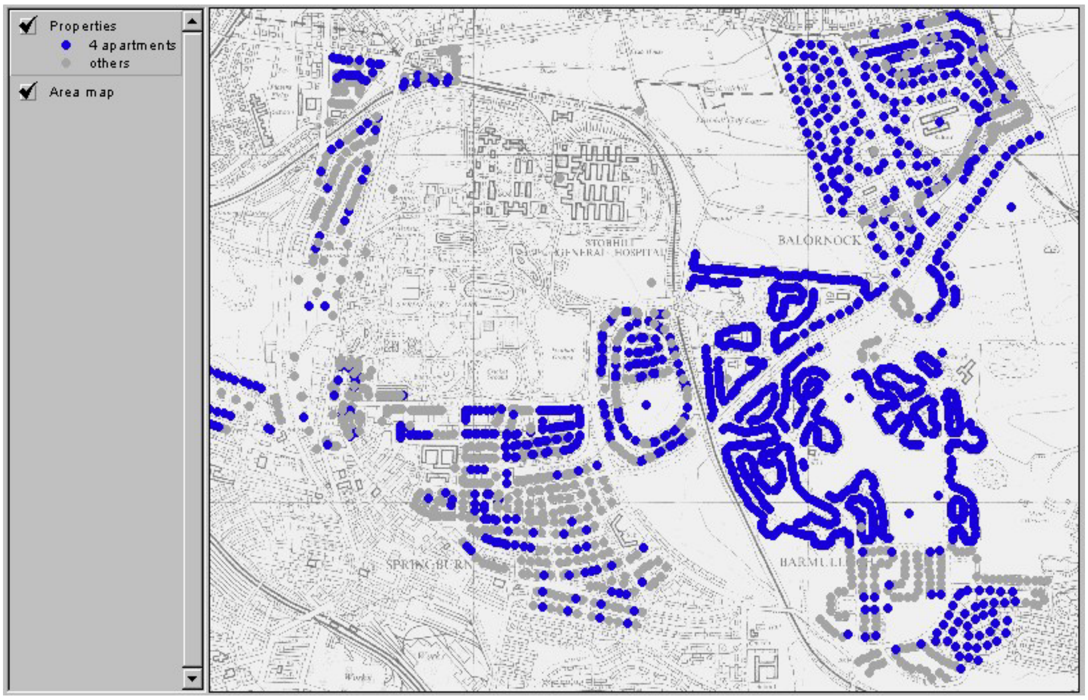


Figure 7-16 Querying properties by a given condition, here 4 apartments.

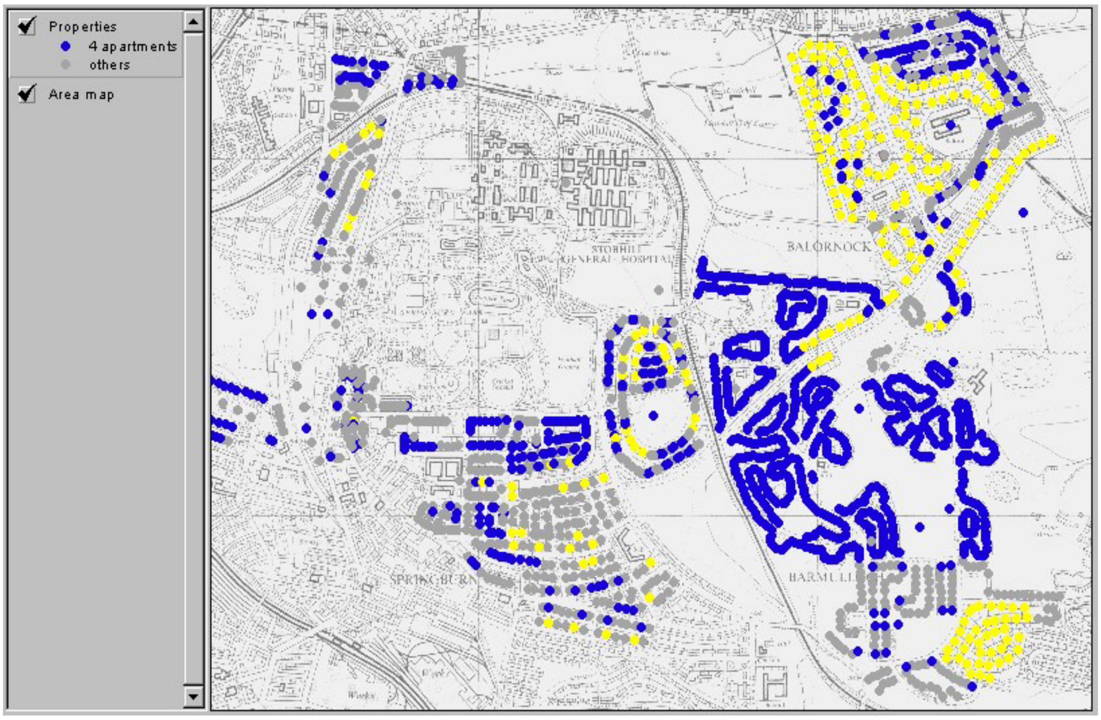


Figure 7-17 Querying properties by the condition high consuming, 4 apartment (yellow points).

The feasibility of Combined Heat and Power (CHP) was now assessed street-by-street on the basis of the distribution of the heat-to-power ratio. Figure 7.18 shows the result. The feasibility is classified into 5 levels: fair (blue) and bad (red) areas are easily identified.

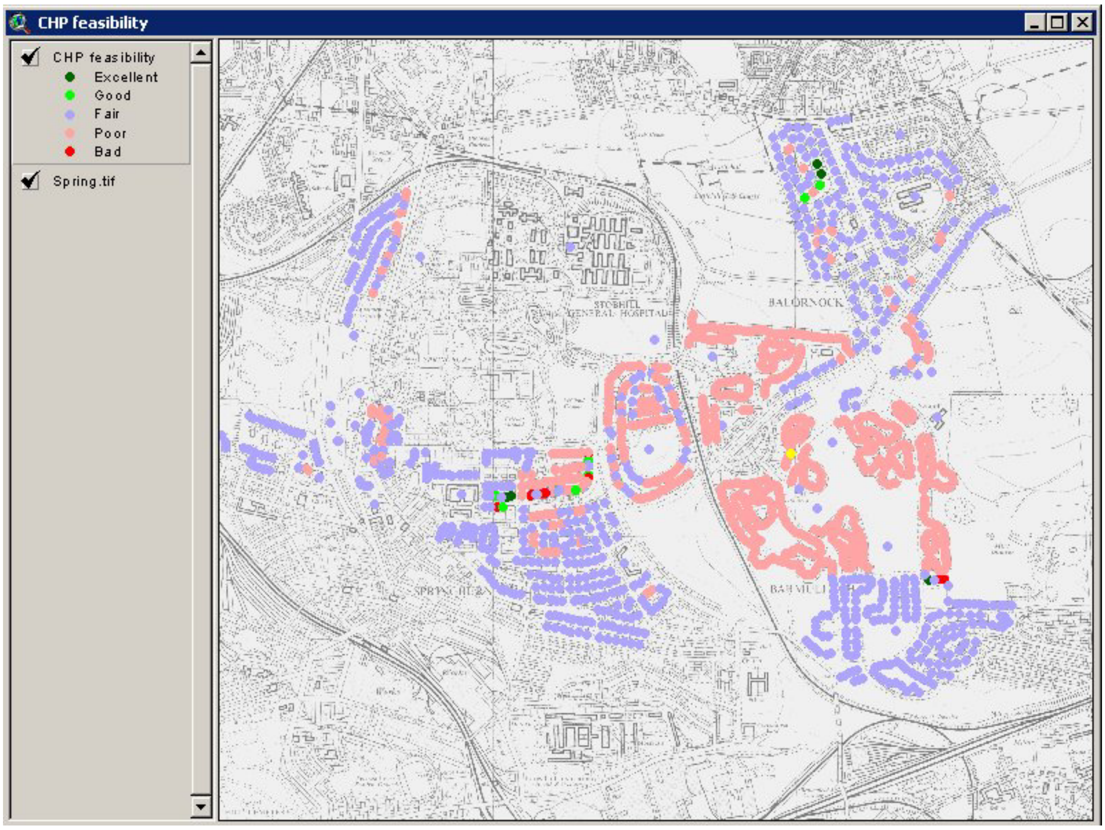


Figure 7-18 CHP feasibility based on the heat-to-power ratio.

7.2.4 Discussion

While the identification of energy demand profiles at the street level is significant for sustainable development, the reliability of the result from such analyses depends greatly on the data accuracy. Unfortunately, the availability of real data is inevitably limited unless all properties are monitored: and the collected data made widely available. Since this is not possible at the present time because of data confidentiality, the use of virtual prototypes based on scrambled real data (or model predictions) is necessary. This will require that scrambling algorithms are reinforced and agreed by the industry.

The reliability of the virtual prototype approach may be improved by adopting building modelling. A detailed simulation program can be used to create typical building types in a local area. For instance, house types may be classified into detached, semi-detached, mid-terrace, multi-storey apartments and so on and endowed with representative constructional attributes. In addition, statistical information based on real but limited data can be used to refine the prototype models by associating it with non-building elements (e.g. occupancy) and providing calibration data to refine and prove models before use. The predicted energy data attached to the prototype models is both realistic and dynamic. Once a reliable database has been established, comprising real and virtual entities, the impact of new energy efficiency strategies may be studied by simply replacing the prototypes.

Once a database is built, it may be used to more effectively engage citizens in energy and environment issues. By increasing the awareness and motivation for energy saving, it is possible to involve citizens in local energy actions. For example, if the facilities of a system such as EnTrak are made accessible through a Web interface, households would be able to obtain information about their property's energy performance over time. By supporting comparisons with benchmark data formed from similar property types, a competitive element may be introduced that has been observed elsewhere to drive down consumption (Westergren et al 1998). To enable such an approach, widespread data accessibility would need to be permitted by the introduction of new legislation. Alternatively, a market mechanism might be introduced that gives customers an energy discount in return for sharing their energy data.

Comparative analysis such as classification, performance ranking etc, within the same category (i.e. similar type houses, same area), may indicate poor/good performers. This does not mean that the data should be open to the public. Benchmark tests can be conducted to locate the best performing properties. The outcome does not need to be identified thus preserving confidentiality. Limited data access by authorised personnel could be permitted by new legislation or via a new energy information service, which gives the customer an energy price rebate in return for sharing their energy data.

7.3 Institutional Scale: University of Strathclyde

7.3.1 Context

The University has been monitoring its energy use since 1995 and adopts a targeting approach to energy management; the Estates Management Department runs this system. Even though Estates Management is directly responsible for energy management, it has no control over how energy is used within buildings. The primary responsibility of the department is with plant maintenance and upgrading to ensure efficient operation. An Energy Management Committee, comprising academic and technical support staff, is responsible for formulating and implementing energy management activities.

A monthly spreadsheet-based report is produced for review by the Energy Management Committee. An office spreadsheet is used to carry out simple cost, consumption and performance investigative analysis. This report contains information on cost, consumption and performance in the form of data plots, regressions, CUSUM statistics and NPI for the University as a whole. Each month, the Committee reviews the energy report with the aim of identifying exceptional events and areas of opportunity. Despite this effort, the Energy Management Committee has not been successful in taking effective action due to a lack of energy awareness and motivation schemes.

Further, there are technical barriers in identifying energy behaviour of the University's buildings and creating effective energy reports for high-level energy managers at Estate Management and Energy Management Committee levels. The University has previously considered individual departmental responsibility for utility budgets and space allocation. However, the plan was not implemented in practice. Although typical benchmark consumptions in UK university buildings for different fuel types can be obtained from Energy Efficiency Office publications (1997), it is difficult to compare buildings with the benchmark consumption. All buildings are multi-occupancy and multi-usage. No building in a university campus is ever typical since certain buildings host different facilities with different energy use characteristics.

Moreover, it is difficult to distinguish the type of building in terms of the classification of energy metering. Some buildings are not metered individually: for example, the James Weir, Royal College and Thomas Graham buildings (all major consumers of energy within the campus) share a single gas meter. It is therefore unrealistic to bill departments in the absence of detailed energy use data. To employ automatic meter reading for individual buildings requires significant investment. Current energy information levels are unable to support an energy management scheme that encourages users to be energy conscious.

The University has established an Energy Statement that conveys its commitment to energy conservation and environmental protection. However, there are few signs to show that the University complies with the policy successfully (Godsman 2002). Energy efficiency campaigns are outdated and are considered ineffective; and no CO_2 targets have been set in order to address a reduction in pollution. Indeed, a survey of staff energy awareness carried out by Dickson (2003) showed that the motivation of staff is almost non-existent. As can be seen in Figure 7-19, the University's views on energy were low-to-medium, and energy users were provided with little information on how energy is consumed. On the contrary, the survey suggested that environmental consciences alone would provide motivation for many people (Figure 7-20).

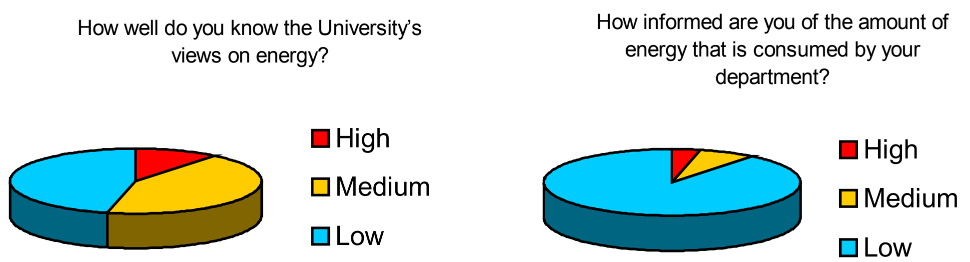


Figure 7-19 Energy awareness survey findings - knowledge of energy situation (Dickson 2003).

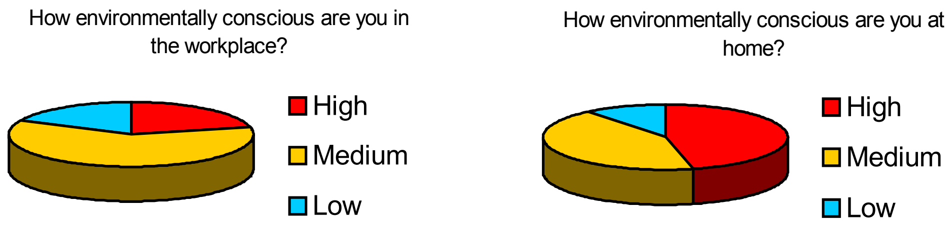


Figure 7-20 Energy awareness survey findings - environmental motivation (Dickson 2003).

Certainly, non-technical aspects (e.g. motivation, marketing, education and awareness), as well as technical aspects, are important to make an effective energy management programme. The motivation and marketing aspects of energy management involved with encouraging energy end-user good housekeeping practices is an area in which the University is currently deficient. No formal means of communication or energy awareness schemes are in operation to influence students or staff whose action directly affects energy consumption. There is little motivation to save energy within the university. While motivation via marketing is required, a good information system must support the scheme.

The aims of this case study are to test the applicability of the EnTrak system in pursuit of improving energy reportage to keep employees and students informed.

7.3.2 Establishing the Database and Configuring the Analysis Model

The University of Strathclyde is split over two campuses: the John Anderson Campus and the Jordanhill Campus. This case study was focused on the John Anderson Campus, located in the city centre. The scope map user interfaces for the University database were created using the maps of the University's official Web site. Figure 7-21 shows scope map interfaces indicating the two campuses of the University and properties (pink colour blocks) at the John Anderson Campus. The campus consists of

44 properties for which there are 128 internal energy accounts (i.e. meter reading points, including gas and electricity; refer to Appendix D for the list of energy meters).

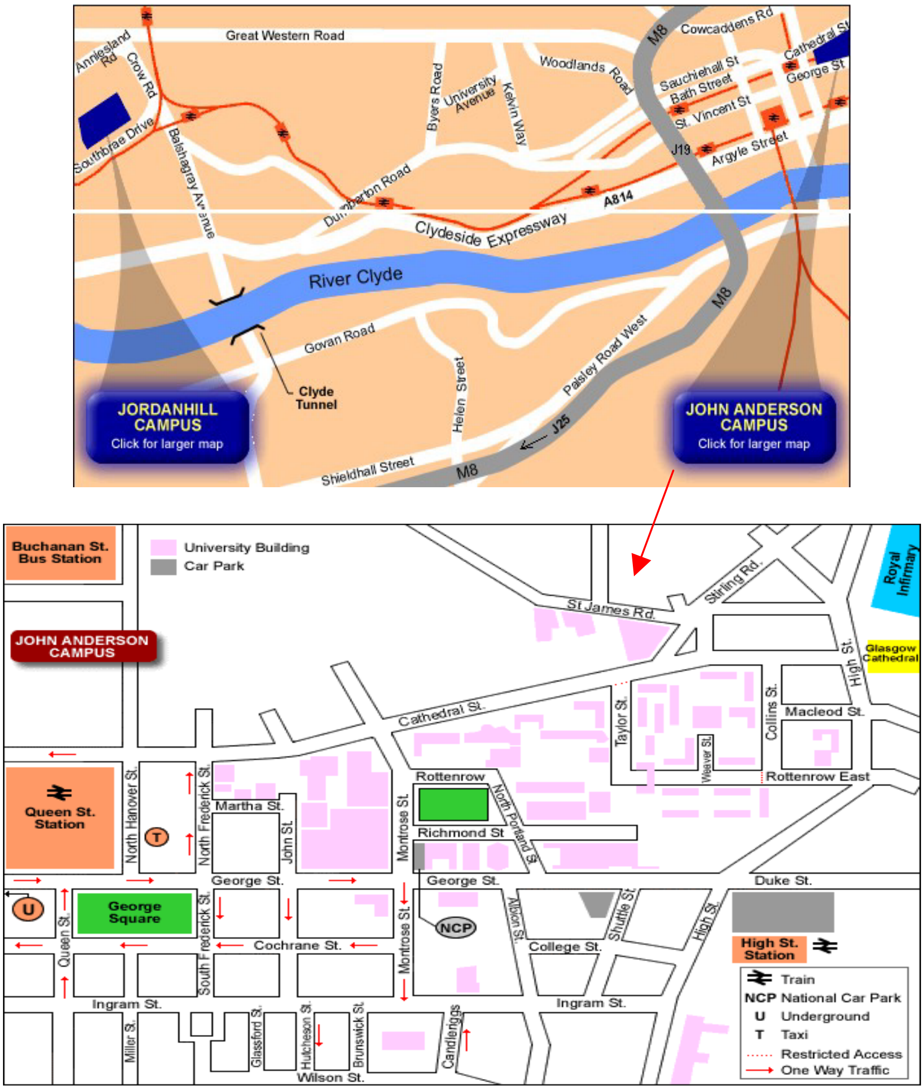


Figure 7-21 Scope maps for the University database.

The consumption data is manually obtained from sub-meters placed throughout the campus. All energy data are unified to kWh for both gas and electricity. These data are stored in an office database in the Estates Department. The main purpose of this database is plant/building maintenance and cross-checking of utility bills. These data need to be imported from the maintenance database to the EnTrak database. The data management for energy analysis was not efficient even if the energy reports are generated regularly for reviewing energy consumption and performance checking. In fact, making the energy reports requires significant manual work due to a lack of an automatic analysis facility and data transforming procedures, which is essential in the context that there is no one responsible for energy management in the department.

In order to improve the data transmission process, transferring data from the Estate Maintenance database to EnTrak has been made coherent by sharing the key information between the two systems. The reference ID for each entity in the Estate Maintenance database was re-used for EnTrak without the need for recompiling. The energy meter ID numbers were also shared in both databases. Consequently, the property data newly registered in the Estate Database can be updated in EnTrak without additional data processing. In addition, the compatibility of the database structures enhanced the data connectivity. The data transmission can be implemented electronically using the University's Intranet.

The entity data imported from the Estates Department were registered in EnTrak. Entity attribution includes year built, number of floors and floor area as well as location details where entities correspond to a portion of a building (e.g. crèche, swimming pool etc) or a cluster of buildings. Property types were allocated to one of four categories (academic, residence, office and service) according to the main activity within the properties. Climate-related data such as degree-days were obtained from a published Website (Vesma 2002).

7.3.3 Outcomes and Applicability

Identifying Overall Energy Behaviour

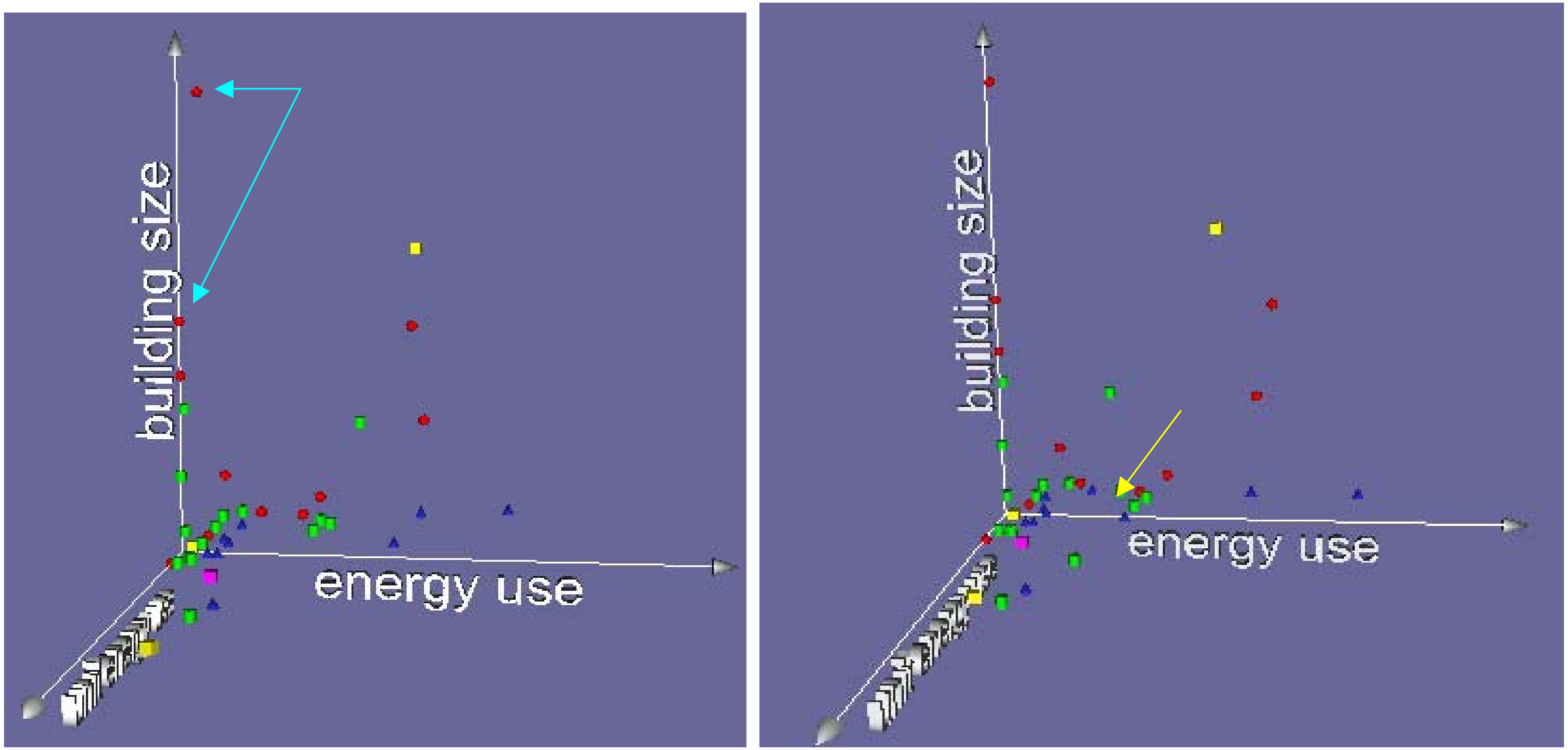
In order to identify the energy pattern of campus buildings, the 3D visualisation model has been established. The attribution mapping was defined as shown in Table 7-6.

Table 7-6 Entity data and attribution mapping.

Entity type	*Color*
Academic	Red
Residence	Blue
Service	Green
Office	Yellow
Auditorium	Purple

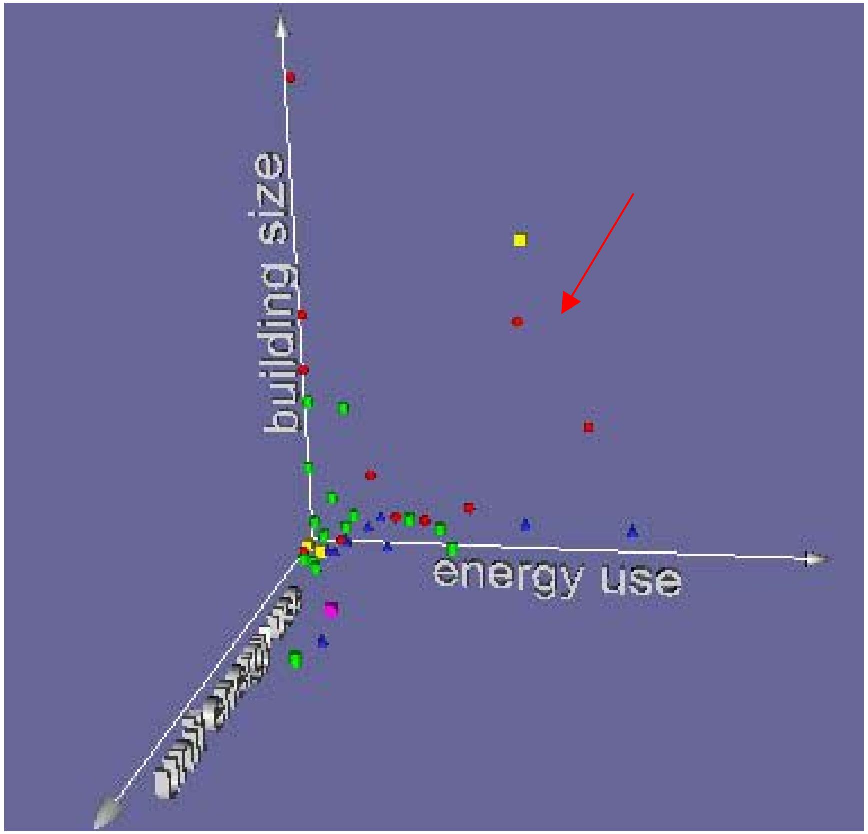
It is not difficult to discover a typical pattern of overall energy use over several years from the outcomes as illustrated in Figure 7-22 and Figure 7-23. Meanwhile, the distributions of the entities scattered in the 3D graph are reflecting against the weather conditions (i.e. annual degree-days). It is informative to compare the 1997 and 2001 pattern. While large buildings supposedly consume more energy, some entities (light blue arrows) are exceptional.

Gas use data is not available separately for the James Weir and Royal College buildings because the gas meters are integrated. Only a small boiler located in the Royal College building is separately monitored. Meantime, the status of individual entities can be recognised. For example, an entry (yellow arrow) can be seen in 1998, which corresponds to the James Goold Hall built in 1998. Any unusual energy behaviour can be identified by looking at the overall pattern (e.g. see red arrow).

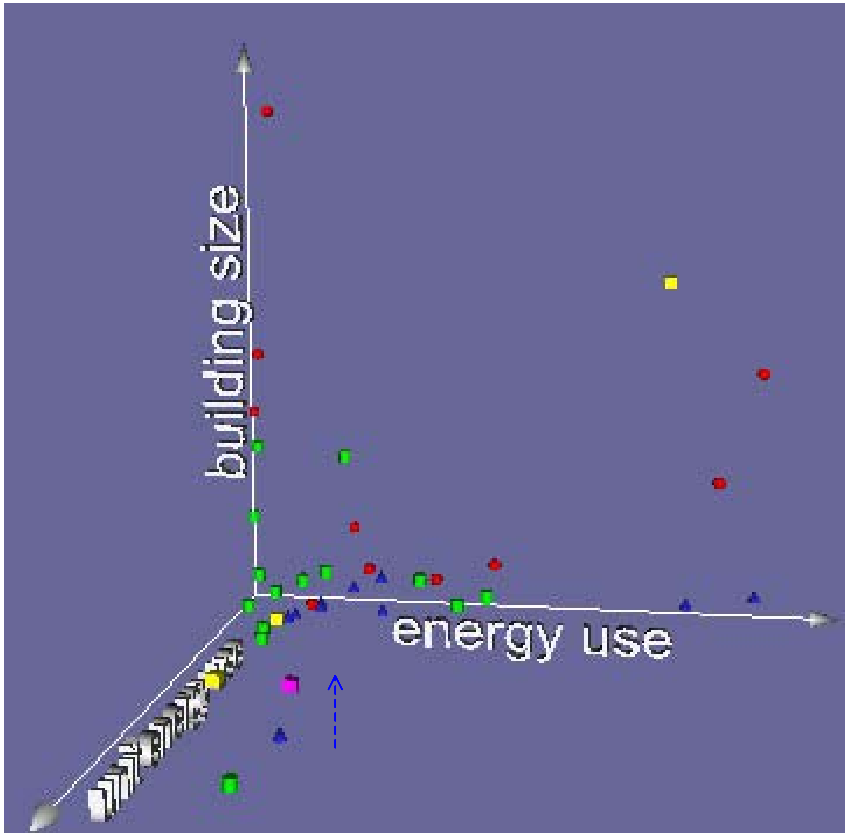


1997 (degree-days: 1680) 1998 (degree-days: 1729)

Figure 7-22 Energy use patterns : annual gas consumption in 1997 and 1998.



2000 (degree-days: 1720)



2001 (degree-days: 1753)

Figure 7-23Energy use patterns : annual gas consumption in 2000 and 2001.

Likewise, problematic entities can be detected by comparing an outcome with the patterns characterised previously; the patterns retains similarity for monthly energy use as well (see Figure 7-24). The energy performance of individual buildings can be checked every month. The energy strategy would be placed on increasing overall energy efficiency of campus entities (e.g. refurbishment, better control, energy motivation etc) and reducing energy use volume (e.g. adoption of renewable energy systems). The effectiveness of the strategy can be assessed again by looking at whether a desirable pattern is achieved (as indicated by the blue circled areas in Figure 7-24).

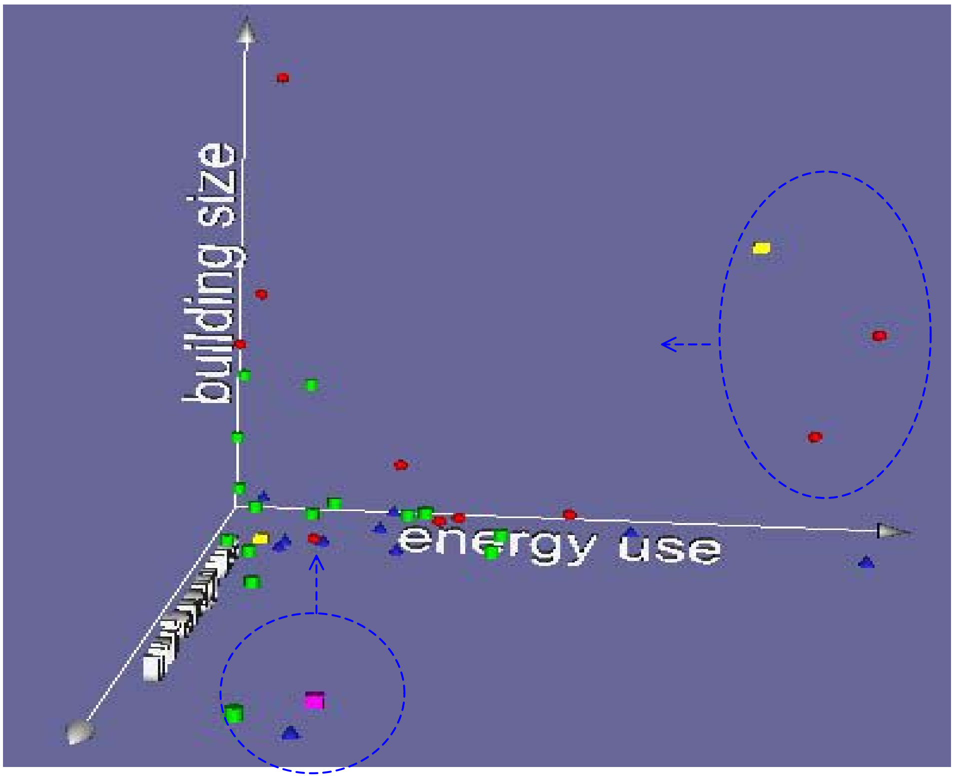


Figure 7-24 An energy pattern based on monthly gas use (January 2000).

Energy Reports and Investigative Analysis

Using the analysis facilities of EnTrak, energy reports can be created efficiently. Energy reports on a scope cover all of the properties within a scope (e.g. all buildings, residences only etc) providing such information as total consumption per utility, breakdown of energy use, gaseous emissions, classification of buildings and underlying consumption trends. The energy reports may be produced for any period or fuel type, which enables side-by-side comparisons.

For example, Figure 7-25 shows the scope map for all buildings at the John Anderson Campus and the outcomes from an EnTrak analysis. Monthly energy profiles are simply generated according to the fuels types. Based on this energy use, gaseous emissions were calculated. The outcome of classification analysis is also displayed where the entities were classified into 5 classes according to total energy consumption to indicate the energy demand spectrum of the scope.

Figure 7-25 An energy report on the 'John Anderson Campus' scope in 2000.

A scope of 'residences', which have individual energy metered every month, was created to enable a more specific analysis. Energy efficiencies and energy demand volumes of residences are identified via the 3D visualisation model. To highlight the residence scope, entities in the data space are coloured in light blue excepting residences (Figure 7-26). The outcome identified Murray Hall as the worst performer among the residences while the biggest demand is associated with Baird Hall.

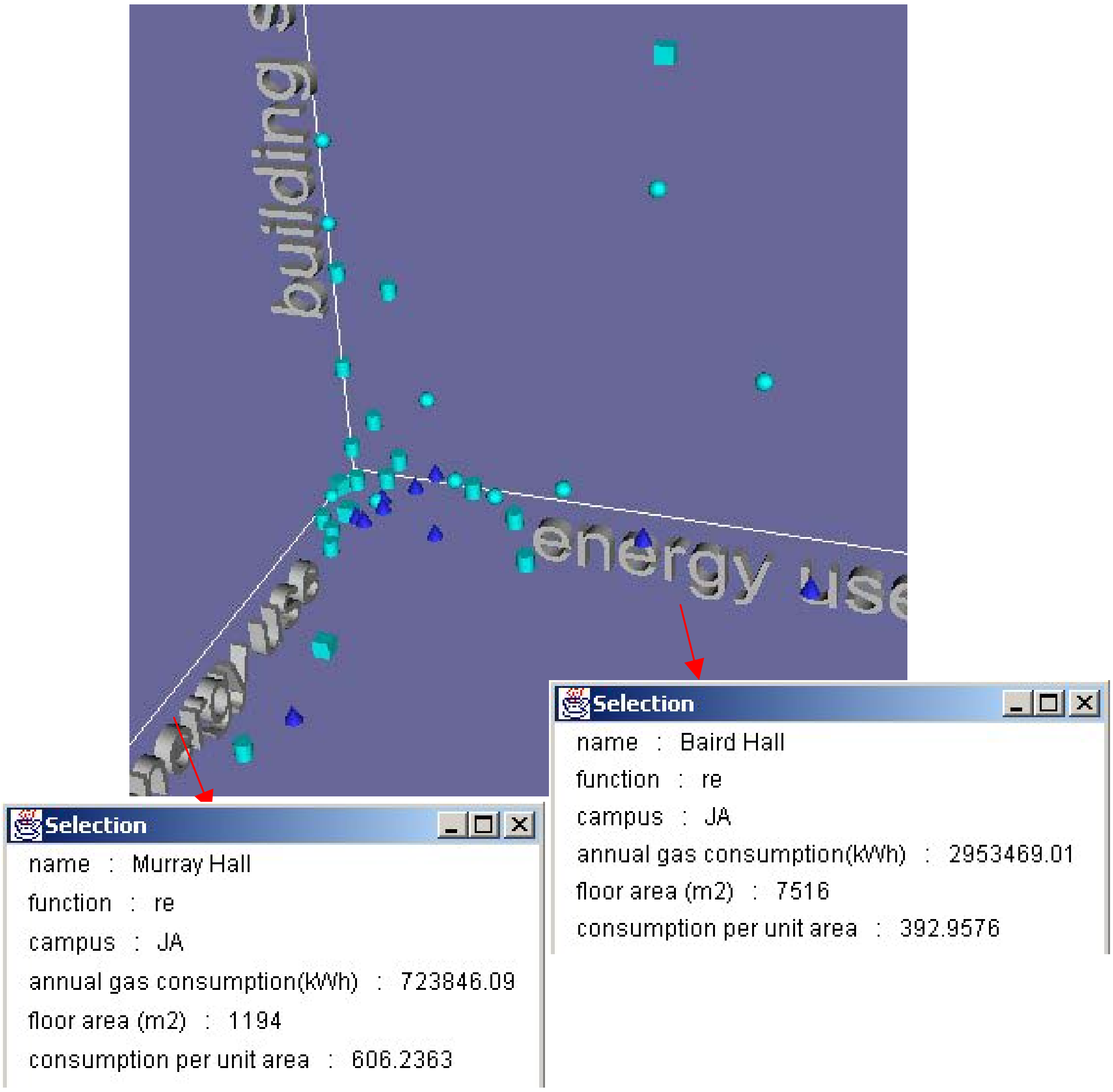


Figure 7-26 Finding problematic entities through the 3D visualization model highlighted on residences.

The consumption of Murray Hall (606 $kWh/m^2.yr$) is much greater than the UK typical consumption of 230 $kWh/m^2.yr$ (Energy Efficiency Office 1997) for higher education residential buildings. While gas consumption is higher than average, electricity is lower (40 $kWh/m^2.yr$) than typical (85 $kWh/m^2.yr$). There were crucial defects associated with space heating. In terms of energy management, Murrey Hall gives rise to the greatest cause for concern.

To explore the energy performance in more detail, an energy report for the 'residences' scope was created on the basis of gas consumption during the period from May 1999 to May 2001. Figure 7-27 illustrates the interactive scope map displaying the location of the residences and the outcomes of the analysis (i.e. monthly energy use profile and regression).

The overall gas consumption profile shows the individual energy profiles for each entity to indicate trends and energy demand scales. These profiles are usually weather and occupancy related. Consumption drops in January due to the Christmas break. Consumption for Baird Hall and Birkbeck Court increases in August due to the opening of these accommodations to the public.

The result from the regression analysis of energy consumption against degree-degree-days corresponds to a correlation coefficient of 0.84. The result of the regression analysis for each residence is shown beneath the graph of the overall regression. As can be seen, Murray Hall has the lowest correlation coefficient at 0.54. This confirms Murray Hall as the poorest performer in terms of plant operation because a larger scatter (i.e. low correlation coefficient) indicates poor control against weather conditions.

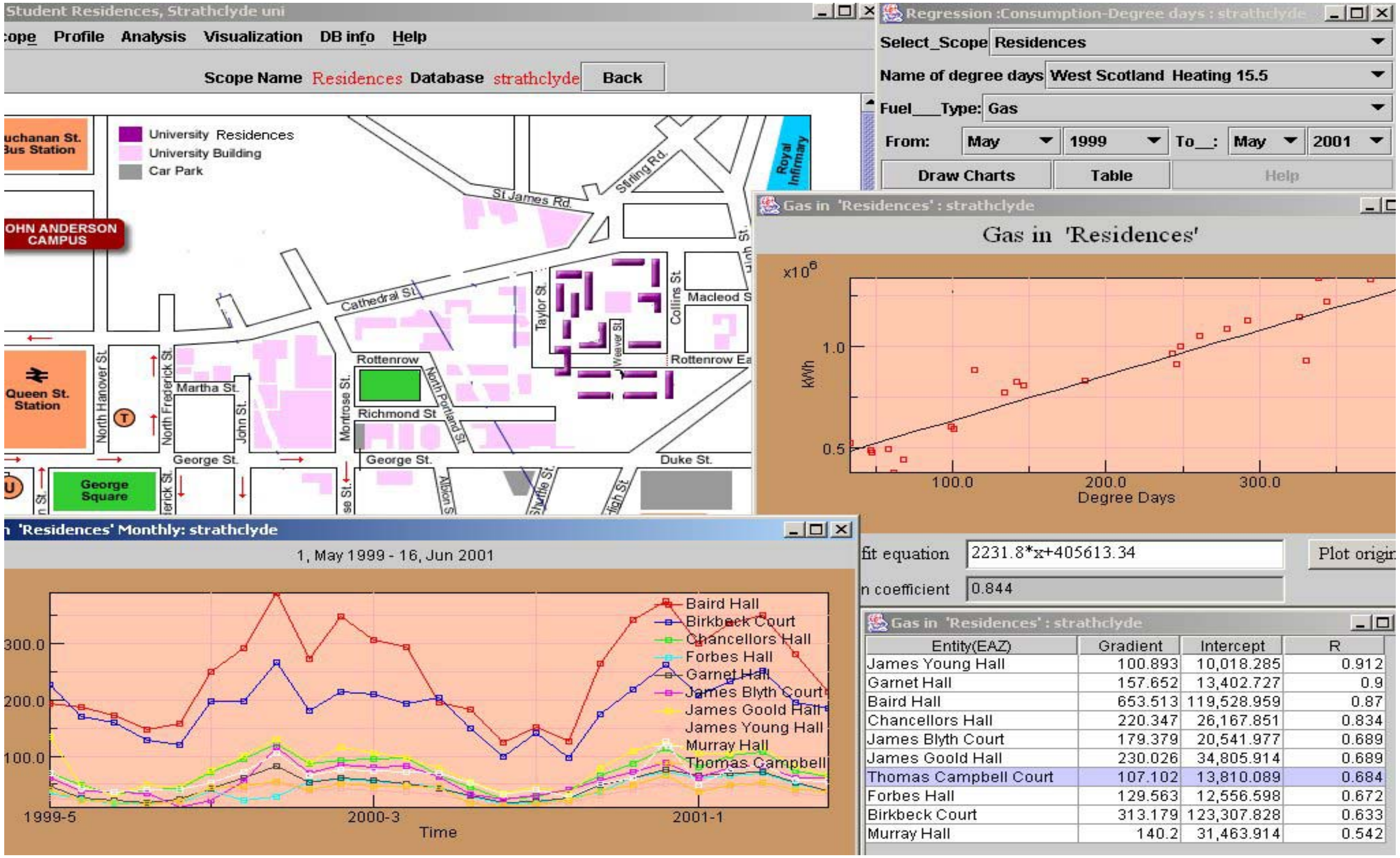


Figure 7-27 An energy report on the 'residences' scope for the investigative analysis.

In fact, Murray Hall does not have thermal insulation in its cavity walls. The control of thermal comfort is local, and all windows can be opened by occupants. It is suspected that occupants are unaware of energy conservation. These negative features probably affected the energy performance of the building. While a significant improvement will be expected by improving the U-value of the building envelope, other remedial actions should be explored by Estates personnel, perhaps by undertaking a detailed simulation of alternative options. Historical metered data available in EnTrak can be used to calibrate the simulation results and predict the cost reduction.

Feasibility test of CHP system

While reducing energy demand by preventing heat loss from the envelope and operating plant more efficiently, an alternative energy supply system could also be adopted. In terms of increasing fuel utilisation efficiency and reducing gaseous emission, a CHP system may be a favourable option. To this end EnTrak may be called upon to produce information on the variation in heat-to-power ratio from which CHP feasibility may be judged.

The data aspect model for the test (i.e. gas consumption and electricity consumption of all residence buildings at various frequency) was implemented by using SQL scripts (see Appendix B.4). Firstly, heat-to-power ratios of all residence buildings were calculated on the basis of annual gas and electricity consumption (Table 7-7). Monthly heat-to-power ratios were then calculated to determine dynamic fluctuations. For example, Murray Hall, the worst energy performer, has a reasonable heat-to-power ratio at 5.8 in annual terms. Murray Hall also shows favourable values at the monthly scale as can be seen in Figure 7-28: such ratios are suitable for a pass-out steam turbine operating with a variety of fuels as indicated in Table 7.8.

Table 7-7 Heat power ratios of residences.

Residence	*Heat : Power ratio*
Chancellors Hall	11 : 1
James Young Hall	9.4 : 1
Murray Hall	5.8:1
Garnet Hall	3.9:1
Thomas Campbell	3.4:1
James Goold Hall	2.8:1
Birkbeck Court	2.5:1
Baird Hall	2.0:1
James Blyth Court	1.6:1
Forbes Hall	1.1:1

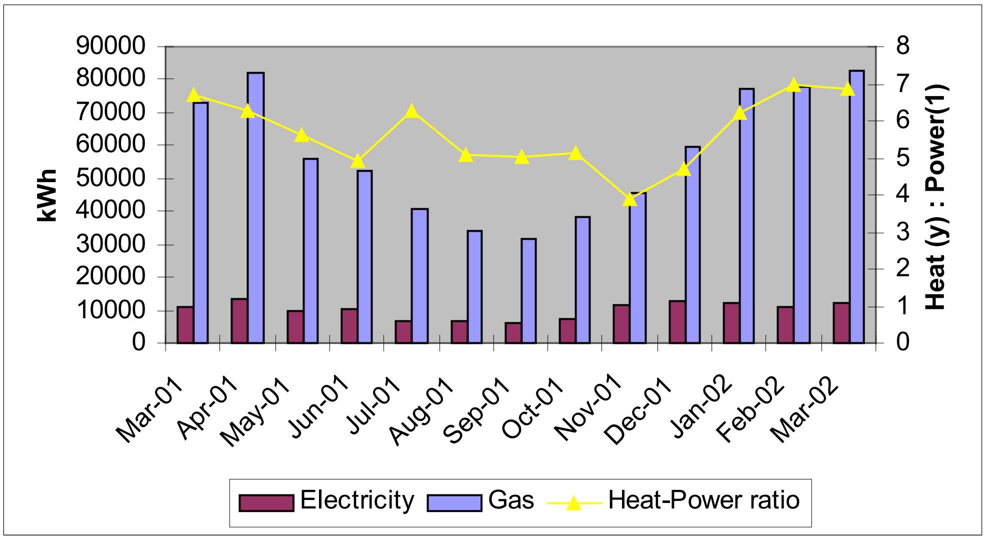


Figure 7-28 Heat-to-power ratio of Murray Hall based on monthly energy use.

Table 7-8 Typical characteristics of CHP systems (Guide 60).

	Spark Ignitiion Engine	Compression Ignition Engine	Gas Turbine	Combined Cycle	Back Pressure Steam Turbine	Pass Out Steam Turbine
Fuel Type	Natural gas, Biogas...	Natural gas, Biogas, Gas oil, Heavy oils	Natural Gas, Biogas, Gas Oil	Natural Gas, Biogas, Gas Oil	All types	All types
Capacity Range	30 kWe to 2 MWe	100 kWe to 20 Mwe	>1 MWe	>3 MWe	>500 kWe	>1MWe
Heat:Power Ratio	1:1 to 3:1	0.5:1 to 1.5:1 (3:1 with boost firing)	1.5:1 to 2.5:1 (5:1 with supplementary firing)	1:1 (3:1 with supplementary firing)	3:1 to 10:1	3:1 to 8:1
Heat Output Quality	LPHW, Steam (rare)	LPHW, Steam	High Grade Steam	Medium Grade Steam	Medium Grade Steam	Steam at 2 pressures
Electrical generating Efficiency %	25-33	35-42	25-40	35-50	7-20	10-20
Overall Efficiency %	70-78	65-75 (75-82 with boost firing)	65-80 (75-82 with suppl. firing)	73-80 (80-85 with suppl. firing)	75-84	75-84

However, in order to achieve a successful CHP deployment, other aspects including financial feasibility and fuel availability must be considered (CHPB 2003). For example, natural gas is used as the preferred fuel for commercial CHP due to its low gaseous emissions and wide availability. Also, heat-to-power ratio for the plant must not fluctuate more than 10% while simultaneous demands for heat and power must be present for at least 4,500 hours a year. More detailed analysis (e.g. hourly-based demand supply matching) should also be carried out.

Improving Energy Awareness and Involvement in Energy Management

In addition to plant maintenance, it is effective to monitor efficient system operation and maintain occupants' thermal comfort. In order to realise an awareness and motivation strategy within the university, energy accounting centres must first be established. An investment in a monitoring system would also be required in order to associate energy performance to these accounting centres. Although a building management system (BMS), which offers the ability to control certain plant characteristics as well as providing an alarm fault function, was implemented within the university, it does not cover all the buildings across the campus, and there is the incompatibility of some older systems. The investment required to establish an energy accounting centre via BMS could be impracticable due to the large financial burden.

As the local area network (LAN) infrastructure covers all campus buildings, the opportunity to utilisie this network for energy management is high. Smarthomes technology as reported in Section 5.3 is expected to find application here. To test the possibility of information network for energy management at the institutional level, the trial deployment of the e-box system was made throughout the Campus

The e-boxes were installed in several campus buildings (Table 7-9), and data from the devices are managed by EnTrak. Since most of lecture rooms have Ethernet sockets for educational purpose, there were no difficulties in finding network connection points for the e-boxes. The monitored data can be displayed via the Web sites in real-time so that Estates personnel and others can monitor environment conditions and energy use.

Table 7-9 List of locations for the e-boxes deployment.

Building	Location	Sensors
John Anderson	Teaching Cluster Level 3 Teaching Cluster Level 4	Temperature & Motion

Architecture	Level 2 East Computer Lab Level 1 Level 3 Studio West	Temperature & Motion
Collins	Court Senate Committee Rooms (2) Cloakroom	Temperature
Colville	Room E330 Corridor outside E330	Temperature & Motion
John Arbuthnott	Lecture Theatre 101 Level 6 Plantroom	Temperature, External Temperature
James Weir	Level 3 Corridor Level 4 Corridor	Temperature
	Room 409, Room 327, Room 313	Temprature & Motion
Curran	Level 3 ITS Desk	Temperature & CO_2
	Level 3 Plantroom	Duct Temperaure
	Level 5 – 5.85	Temperature
Estates Manangement	Level 2 BEMS Room Level 2 Conference Room Level 2 Open Area	Temperature

Figure 7-29 shows a lecture room where an e-box system has been installed. The e-box was placed in the rack alongside the available audio/video system. Figure 7-30 shows a Web interface displaying indoor temperature in the room during a period of overheating.

It is expected that this information facility will help people to be more aware of energy use and to become involved in the institutional energy action. Temperature and motion sensors were installed with the e-boxes in lecture rooms for overheating detection. When overheating occurs, the e-box automatically issues an alert to the Estates department. The thermal conditions around the campus are monitored at high frequency and the aggregated data used within energy analysis. This is beneficial in that such monitory can be established at low cost.

Figure 7-29 A lecture room (M409) with an e-box installed.

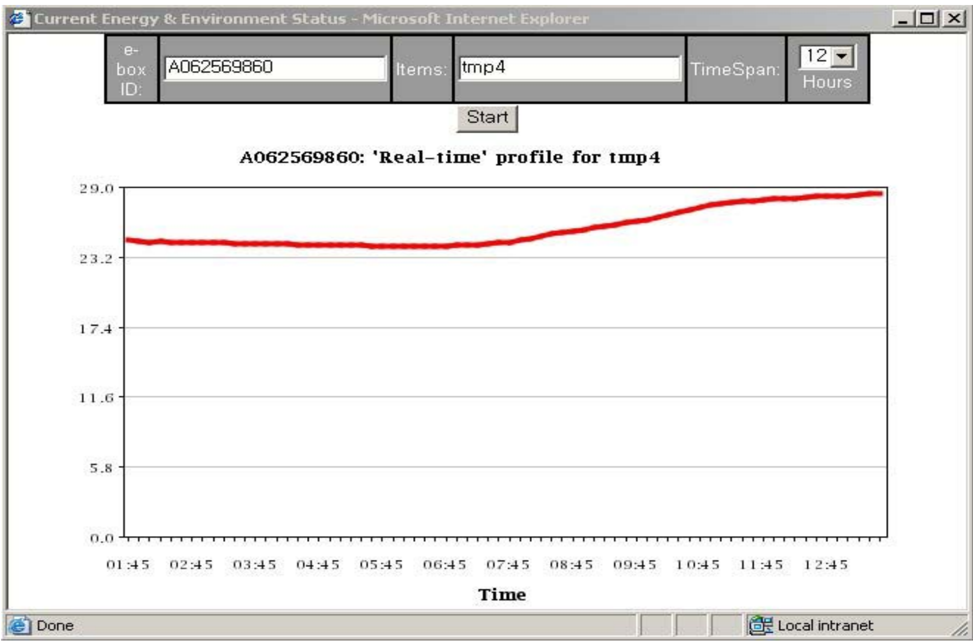


Figure 7-30 A Web interface displaying indoor temperature in the room (M409).

7.3.4 Discussion

Identification of energy patterns using 3D data visualisation gave a new approach to support in setting up energy strategy and assessing energy performance in no time. This pattern-based analysis approach enables benchmarking and instant reaction against possible system failures or poor operation that otherwise would go undetected.

Routine reports can be generated automatically using analysis facilities available in EnTrak. The automatic report generation is expected to reduce office work load on Estate Management staff and allow energy managers to scan energy use on demand.

Further, it is anticipated that a Web-based user interface for energy management could be established to share energy information instantly as shown in Figure 7-31.

The Web interface allows top-level decision-makers (e.g. Energy Committee) and energy managers (with departmental responsibility for energy management) to obtain energy information via a Web browser. Such on-line reporting would support the routine implementation of energy strategies. For instance, if the responsibility for energy management was distributed across departments, the regular publication of a league table of performance could be accompanied by an offer to return a portion of the savings to the departmental budget. If a well-defined scope of entities is defined, the subsequent analyses will be more productive. In the long term, the definition of zones and individual meters should be implemented for the allocation of energy responsibility.

Since the data travels via the Internet it could be transferred to a possible central database where data from other institutes are collected. Alternatively, if databases are interconnected via a common protocol (i.e. SQL), they can be shared with each other. This means that real-time benchmark comparisons with other university's entities is possible. In order to realise this, it is necessary to define entity types and associated energy data.

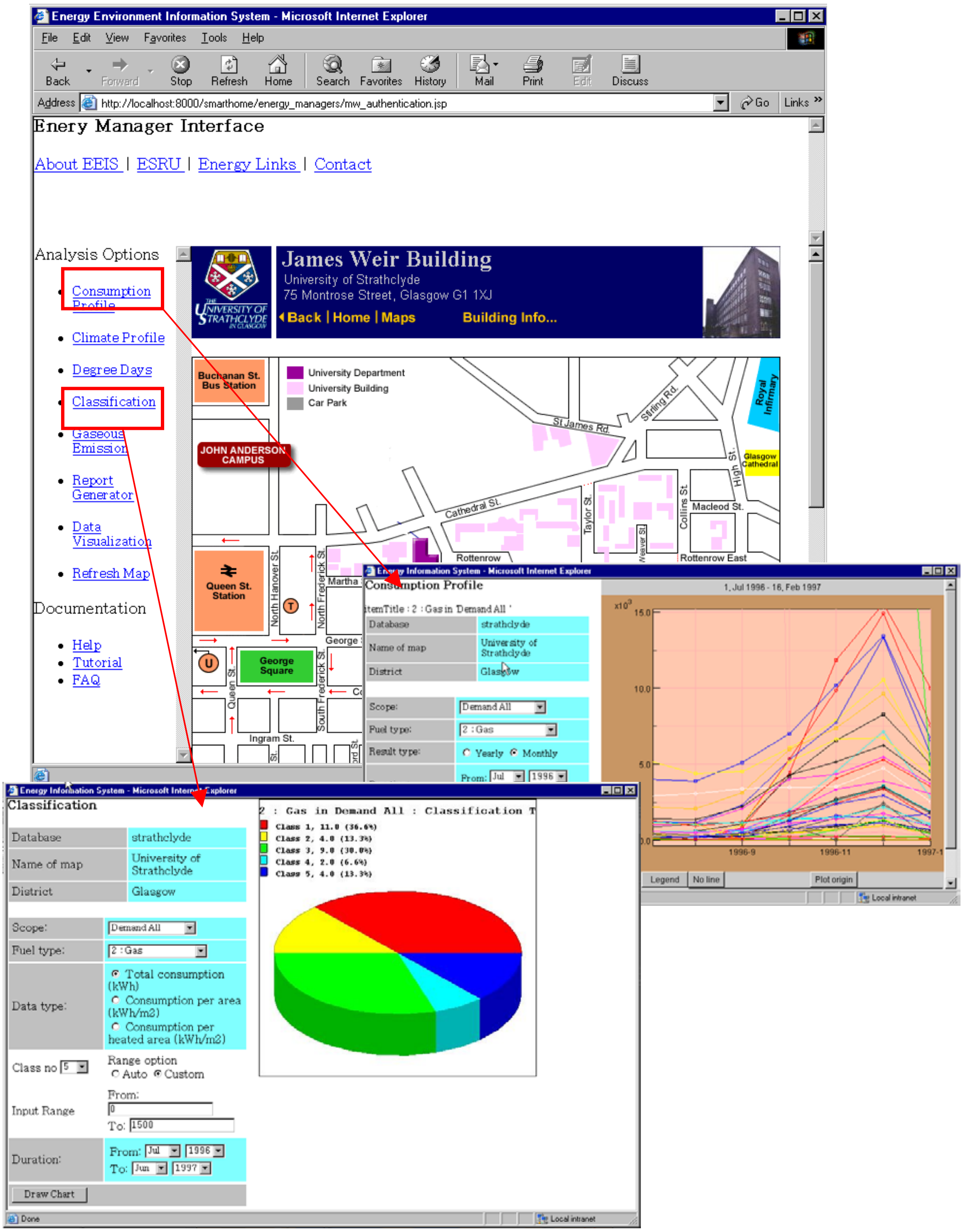


Figure 7-31 The envisaged Web-based energy information service.

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Chapter 8 Conclusions and Future Work

8.1 Conclusions

Recent energy policy and actions have begun to force organisations to form partnerships to tackle the common problems associated with reducing energy use and gaseous emissions. Various types of decision-makers (e.g. policy makers, developers, local authorities, energy managers, home occupiers etc) impacting on energy and environment issues require support to inform their decisions at different levels. Although there are many software systems available, collecting foundational data is non-trivial since these data are scattered across different locations and held in different formats. Furthermore, some of these data are subject to the Data Protection Act. It is therefore difficult for decision-makers to obtain up-to-date information on demand due to the lack of appropriate data sharing mechanisms between organisations. Such barriers prevent end-users of decision-support from making use of integrated and extensive information.

This study set out to develop a technical solution that removes this barrier. To construct the envisaged information sharing system between energy partnerships, a prototype Energy Environment Information System (EEIS) was suggested on the basis of the Internet infrastructure. Current information technologies have been reviewed and the outcomes related to the needs of the EEIS. The functional requirements of the EEIS have been specified. Through the reviews, the following requirements for system capabilities of the EEIS were identified:

- scalability and flexibility of the underlying database system to manipulate diverse and extensive information resources;
- multi-type user interfaces and efficient information delivery; and

- o integration of data from a variety of sources (meter readings, field monitoring and modelling) with information sharing between different users via the Web.

Taking account of the availability of Information Technology, this study has focused on developments in the following areas:

- o a data model and management system that accommodates extensive and multi-scale energy/environment data;
- o a user support system and analysis model that enables strategic and tactical decision making in a coherent manner; and
- o on-line system connectivity with third party applications covering integrated energy modelling and internet-based monitoring and remote control system.

The prototype of the EEIS has been implemented in a software package called 'EnTrak'. The applicability of EnTrak was tested with real data. The conclusions of the study are as follows.

Data model

The data model was developed on the basis of the relationship between an entity and its dynamic behaviour in an energy/environment context. An entity data model was defined and attributed with the generic properties of demand and supply side system. Specific instances of the entity such as a building, a transport system or a renewable energy system then inherit these properties. Although only some of representative energy systems (i.e. building, PV, wind turbine) have been implemented in this study, the flexibility of the structure of the data model allows various types of energy demand/supply systems, even future possible systems, to be added without affecting the whole structure of the data model. The dynamic data model (i.e. time-dependent data such as weather, energy) has been designed to accommodate the various data formats, frequencies of capture and scales. While the open structure of the data model will allow extensive information storage, the performance of the data query is likely to depend on the complexity of the query rules in the implementation of SQL statements.

User support system

A scope is a "data view" defined by selecting entities of interest according to descriptive parameters, location etc. A scope consists of a set of entities, and is exploited to make a data aspect model with other dynamic data. The flexible analysis model, comprising 3 tiers (data pool, analysis tool and result view), was designed to increase portability of the data aspect model and analysis components to meet the different demands from decision-makers operating at different levels. Ultimately, this data handling mechanism supports multiple user interfaces, each utilising a common data resource and manipulating the EEIS data for multi-variant and multi-scale analyses in a coherent manner.

3D data visualisation

To improve knowledge extraction in the EEIS, a new approach to exploratory analysis has been established based on a 3D data visualisation technique. A data space model was configured and examined by using energy data collected in the field. It was shown that 3D data visualisation gives a good insight into the energy performance of properties. The possibility of the pattern-based assessment of strategic and tactical energy actions was studied for supporting, especially, large-scale energy/environment decision-making. While such a qualitative approach is efficient at identifying energy patterns at the large scale, the interpretation of a pattern requires user skill. The visual effect of the outcomes depends on how the spatial dimensions and attribution dimensions are assigned to data items. The scale adjustment of the dimensions is also important to obtain informative views from the visualisation tool. Therefore, the assessment of energy/environment performance using this analysis model is an art rather than a science.

System connectivity

Coupling with GIS allows the automatic interrogation of spatial data in support of strategic decision-making involving a broad geographic area. Combining GIS spatial data and EEIS energy/environment data enables more effective sustainability appreciation and intervention. The energy simulation package can support data generation for future options appraisal or virtual metering. An Internet-based collaborative decision-making system was shown to be an efficient procedure undertaking building simulation studies.

The system connectivity of the EEIS permits the following capabilities.

- The integration of virtual and real data in real-time by combining such entities in a consistent model.
- High resolution and high quality data: large volume energy/environment data may be monitored at high frequency through electronic data channels with no human intervention.
- Concurrency of strategic, tactical and operational decision-making. By sharing monitoring and control channels with various decision-makers in real time, problems may be rapidly detected and rectified.

Eventually, coupling with modelling packages such as building simulation and GIS and Internet-based electronic communication systems will enable a deepening of the quality of the information available in estate performance and options for change.

EnTrak system and applicability

As a specific implementation of the EEIS, the EnTrak system was developed based on Java technology. Component-based API packages were developed to provide the functionality required by the users' interfaces. The applicability of EnTrak was tested with real data collected at three different scales: regional, municipal and institutional. The analyses correspond to various scenarios of energy action planning, scales, technical circumstance associated with data resolutions and quality. As various procedures and sources of data collection were involved, some practical issues arose:

- significance of data availability and validity; and
- analysis approaches responding to different data resolution.

Data availability and validity are critical to the provision of valuable information. It was observed that preparing valid data is a non-trivial exercise that consumes significant resources. Concerning large-scale energy management (e.g. of local authority estates), data validity is likely to be low with many items being unavailable. This problem can only be resolved by establishing more robust data collection channels (e.g. Internet-based meter reading and data transmission). At present, it is impractical to collect energy data for all properties. Conventional monitoring and targeting tools have failed to overcome this barrier. The Internet-enabled approach of the EEIS represents one possible solution because such a massive monitoring operation can be implemented with low cost.

By establishing a coherent database in real time, the overall energy performance of properties at the regional scale can be assessed qualitatively using data visualisation tools. The outcomes can lead decision-makers to identify problematic entities that can then be investigated in more detail before deciding on remedial action. Once such action has been implemented, the impact becomes immediately known due to the real-time nature of the decision-support tool.

High resolution data relating to elementary entities such as households offer substantial opportunities to identify trends at the urban scale. Where there are no access restrictions (e.g. the user is the data owner), the establishment of a high quality database at low cost should be possible. Where data confidentiality applies, simple scrambling mechanisms may be employed or market mechanisms used to create value proposition for the data owners (e.g. citizens or utilities).

Delivering information based on up-to-date energy data is the prerequisite of future 'energy alert' actions. Significantly, poor performance can often be identified by just observing real data in real-time and comparing trends to acceptable benchmark data or historical trends. Experienced personnel can then be dispatched to investigate problems and devise plausible solutions without delay. The EnTrak prototype has demonstrated the potential of such an information management system to deliver essential data in real-time and allow users to observe property performance in support of their decision-making.

In conclusion, the concept of an EEIS started from the basic idea of bringing people together on-line to focus on shared problems regarding energy and environment performance. This study is a demonstration of an approach to collaboration between citizens, institutions, management organisations and utilities. It is likely that the widespread adoption of broadband will open up the possibility of new energy and environmental services that can be operated at the large scale. Such new information sources have the potential to deliver benefits to citizens and professionals such as energy managers, designers and planners. This thesis has established a prototype integrated information system and examined the range of possible network-based services for supporting collaborative decision-making in energy action planning.

8.2 Future work

Simulation-assisted control

There has been considerable research into predictive control, using stochastic models, fuzzy logic control, neural nets and the development of self-learning algorithms. A clear drawback to such control methodologies is the requirement for extensive data. Even the best-trained self-learning controller cannot be exploited beyond its range of experience. There are few interactions between the controlled system and external parameters such as climate and occupants. With passive buildings employing natural resources, such as daylight and free cooling, control actions become complicated due to interactions between the elements of the controlled system. Alternatively, Clarke et al (2002) demonstrated the feasibility of predictive control using a physically-based thermal simulation program.

In the study, data were collected by a data acquisition system, and used as real-time inputs to the ESP-r simulation program. A number of simulations were then run to determine the optimum start time, for example, for a heater to bring the room temperature to a particular level by a certain time. As an alternative to the data acquisition system, a data transaction mechanism can be established using the Internet-based energy service system; this collects data and transfers the simulation-predicted control action back to actuators via the EEIS communication infrastructure. Also, external data such as weather can be broadcast and shared with different entities in real-time. This feature will bring benefits that encourage further development of the idea (e.g. testing on a full-scale building subject to external climate variation, integrating improved short-term weather prediction algorithms into the simulator and developing calibration strategies). In addition, if control algorithms are embedded in the local gateway system (i.e. e-box), both short term (i.e. response time in seconds) and long term (i.e. response time in minutes) control algorithms may be implemented simultaneously.

Collaborative decision-support system

As the basic data transaction between components via the Internet has been established, more sophisticated services could be added such as energy action prediction using detailed simulation programs, active demand management and renewable energy trading. Fujii and Johanneson (2003) reported the development of a method where simulations are combined with measurements of parameters for each apartment in a multi-family dwelling as a basis for a fairer system of billing. Similarly, an energy prediction service could be implemented consisting of simulation tools, support databases and appropriate user interfaces. In order to realise such a service, the simulation tool should be able to be exploited by end-users without the need for system installation, maintenance and application.

An example is the integration of the EnTrak and MERIT system (Born 2001), a decision-support tool for renewable energy systems deployment appraisal. Energy demand and weather data can be imported to MERIT where best matches with renewable energy supplies are determined. The outputs from these renewable components are then stored as new entities within EnTrak enabling the side-by-side display of demand and supply. One of the benefits from constructing the Internet-enabled database is the accessibility for third party software packages to create different uses of the information for different types of users.

Demand-supply matching control

As the renewable technologies are typically connected into the electrical supply infrastructure at distribution and supply working voltage, higher levels of local network penetration will require greater levels of control if network integrity is to be maintained. In terms of control, necessary actions must be implemented within the required time scales to maintain network stability. In order to achieve this, it is crucial to predict:

- the magnitude and rate of change in demand, based on trends and weather analysis; and
- the magnitude of the power supply from renewable generation plant based on anticipated weather.

The time steps and response time characteristics are short, in the order of seconds, as required for electricity demand/supply control and matching.

Conner (2003) developed a Real-time Embedded Dispatch Manager (REDMan) algorithm to enable the integration of small heterogenous renewable supply technologies and electrical power demand/supply matching. REDMan comprises sources of power, demands of power, a central dispatcher, and a communications system, which allow messages to be passed between them. Physically, it consists of several computer programs (agents for sources and demands, and a dispatching program) running on one or more computers or embedded controllers. These programs may be interconnected by an EnTrak Internet connection. Within this framework, the controller serves to prioritise demand/supply matching. Consequently, EnTrak can assist demand/supply matching and control required by the move towards distributed energy generation.

Graphic indices for the perceptual evaluation of energy patterns

In this study, it has been shown that the data visualisation technique can provide decision-makers with informative outcomes for supporting energy action planning. As more high quality real and virtual data will be available due to the adoption of on-line energy services, various 3D visualisation analysis models could be developed for different purposes. Dynamic data may allow dynamic graphic indices representing temporal energy patterns. Various parameters associated with social and economical aspects could be incorporated to create informative visualisation models.

However, since the types of entities and the scales of energy data are variable, according to databases established in various organisations, the 3D visualisation model of one organisation cannot be compared with other organisations unless the data model is shared. As the involvement of users is essential in defining a 3D model, the interpretation of outcomes is only possible by the users. This makes the analysis model relative and subjective. Universally acceptable models must be developed in order to apply this technique for more reliable assessment (e.g. benchmark testing). The procedure of data preparation and the definition of visual objects must also be refined.

In order to extend the 3D visualisation model to give more reliable evaluations of energy performance, informative performance indices are required. The purpose of a graphic index is to facilitate a rapid identification of performance patterns within groups of properties in a large-scale energy management context. For example, target zones defined in the virtual data space may be added to guide energy managers and policy makers towards problematic phenomena. Because the diagnosis is based on a relative comparison between homogenous entities, the approach is less controversial than existing statistical indices.

The development of such a graphic index would make it possible to set up an automatic process for dimension mapping and scale adjustment according to the nature of the graphic index. That said, it is possible that, in future, typical patterns might be identified that would support an automated search procedure. Such patterns could be used as a graphic index that describes the overall status of a performance and enables comparisons with other scopes.

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Appendix A. EnTrak Installation

1. Pre-requisite

Log-in as administrator. It is necessary to install Java Virtual Machine(JVM) version 1.2.1 or higher before installing EnTrak (version 1.3.1 is recommended).

Download JRE 1.3.1 for Windows from http://java.sun.com/j2se/1.3/jre/download-windows.html

Set the path to include the JVM.

To set the path, go to the 'environment' option in 'System property'

(in Windows 2000, Start>>Setting>>Control Panel

>>System>>advanced>>environmnent Variables),

and select the variable 'Path' to edit the path.

NOTE: Version 1.4 or higher may have problem in running the Java 3D data visualisation tool.

If you have already installed JVM, check the version and re-install JDK 1.3.1 if the version does not match the requirement.

Note: If there is the older version installed, delete all files including the directory where the package is installed (i.e.'C:\entrak_demo'). Make sure to delete '\.entrak' directory under the user Home directory (i.e. C:\winnt\profiles\user_name\ for MS windows NT, C:\Documents and Settings\username for windows 2000).

2. Installation

2.1 Unzip the entrak_demo package using Winzip in C:\ (Otherwise you need to re-edit 'entrak_demo.bat' to change the path for Java parameters.)

2.2 Install mySQL server.

Double click 'setup.exe' in 'c:\entrak_demo\mysql\installation'.

You MUST install the server in 'c:\entrak_demo\mysql'.

Copy 'my.ini' file from 'c:\entrak_demo\mysql' to 'C:\Winnt'.

NOTE: the post fix of the file name (my.ini) is often not seen in Window Explorer.

2.3 Install MapExplorer2 GIS application.

Double click 'setup.exe' in c:\entrak_demo\gis_view\installation.

Install the GIS application in c:\entrak_demo\gis_view\'.

The installation program will create 'MapExplorer2' directory.

2.4 Register energy data into ODBC to make it available to other applications

(i.e. Data in 'c:\entrak_demo\mutil_dimension_visualisation\data' directory should be registered as an ODBC data source named '3d_sample')

- go to 'start/settings/control panel' in Windows NT, or 'start/settings/control panel/administrative tools' in Windows2000

- open 'ODBC data sources administrator' by clicking 'ODBC data sources' icon.

- open 'create new data source' panel by clicking 'add' button in 'user DSN' tab.

- select 'Microsoft Text Driver[*.txt;*.csv]' (double click the option).

- type '3d_sample' in 'data source name'.

- unclick 'user current directory' to set up your directory.
- click 'select directory'.
- select 'c:\entrak_demo\Multi_dimension_visualisation\data'. and click 'OK' button.
- close 'ODBC data sources administrator' by clicking 'OK' button.

You will need 130 Mbyte free to install the whole package.

IMPORTANT NOTE: Make sure that the directory of 'c:\entrak_demo\mysql\data' is permitted to write.

3. Running

You MUST run mySQL server before running EnTrak-demo. To run mySQL:

Double-click 'winmysqladmin.exe' in 'C:\entrak_demo\mySQL\bin' in Windows Explorer.

NOTE: To check if the server is running properly, find out the icon of traffic signal at the right bottom corner of the screen and see if the green light is on. If it is off, click the right button of your mouse over the icon, select 'winnt'and click 'Start the server standalone'.

Finally select 'yes' when a pop-up message comes up asking to start mySQL server.

To run the EnTrak demo:

Double-click 'entrak_demo.bat' in 'C:\entrak_demo\bin' in Windows Explorer.

To run data visualisation tool:

Click 'run_data_visualisation.bat' in c:\entrak_demo\bin'.

4. Tutorial

To explore the EnTrak demo, follow the tutorial file in: C:\entrak_demo\help\Tutorial\content.htm

To see a demonstration of energy data visualisation, follw the instruction of 'Readme.txt' in 'C:\entrak_demo\Multi_Dimension_visualisation'.

5. Help

For help on SQL see:

C:\entrak_demo\entrak_java\help\sql_tutorial\sqltut.htm

NOTE: open the tutorial file using a web browser.

Appendix B. SQL scripts

B.1 Creating New Database ‘test’

DROP DATABASE IF EXISTS test;

CREATE DATABASE test;

USE test;

```
create table entity ( ref char(25) not null, name char(40) not null,entity_type char(4)
    not null,  data_type char(4) not null,    sort_code_1 char(4), sort_code_2 char(4),
    add_lin1 char(30)   null, add_lin2 char(30) null, add_lin3 char(30), post_code
    char(10) null,  district char(4), gis_xref decimal(10,2), gis_yref decimal(10,2),
    grid_ref char(10), construction_type char(4),  ownership char(10), climate_site
    char(20), built_date date);
```

```
create table building ( ref char(25) not null, building_ref char(25),  exposed_area
    decimal(8,1) null, volume decimal(8,1) null, flr_area decimal(8,1) null, ht_volume
    decimal(8,1) null, ht_flr_area decimal(8,1) null, transp_area decimal(8,1),
    transp_type char(4), opaque_area decimal(8,1), opaque_type char(4),
    system_type char(4), occupancy_ref char(10) null, operation_ref char(10)  );

create table energy (ref char(25) not null, meter_id char(20) not  null, m_number
    char(20) null,  ac_no char(20) null, avail decimal(14,2),  supplier char(4) null,
    fuel_type char(4) not null, load_type char(4),  r_type char(4) not null, tar_id
    char(4) null, from_datetime datetime not null, to_datetime datetime not null,
    dial_1  integer( 12 ) null, advance1 integer( 12)  null, md1 decimal( 10,2) null, pf1
    decimal( 8,6) null, dial_2  integer( 12 ) null, advance2 integer( 12)  null,   md2
    decimal( 6,1) null, pf2 decimal( 6,4) null,  cost decimal(20,2) null, tot decimal(20,
    2) not null   );

create table indoor_climate ( ref char(25) not null,  ic_code char(4) not null,

    datetime datetime not null, ic_item char( 8 ) not null, value decimal(10,3) );

create table climate ( climate_site char (20) not null, climate_code char(4) not null,
    datetime  datetime not null, item char( 8 ) not null, value decimal(10,2)  );

create table climate_espr ( climate_site char (20) not null, datetime datetime not null,
    ambient decimal(4,2),   dir_solar decimal(5,1), diff_solar decimal(5,1), wind_speed
    decimal(4,2), wind_dir decimal(4,1), rh decimal(3,1) );

create table climate_site ( climate_site char (20) not null, coord_code char(4) not null,
    ref_x decimal( 10,2) not null, ref_y decimal(10,2) not null);

create table deg_days ( dd_code char(8) not null, type_dd char(4) not null,    date date
    not null, dd integer(8) not null, climate_site char (20)  );
```

create table gas_emission_factors(region_code char(4) not null, gas_emission_code char(5) not null, date date not null, fuel_type char(4) not null, gas_type char(4) not null, factor decimal(12,2) not null);

create table operation (ref char(25) not null, op_code char(4) not null, datetime datetime not null, op_item char(8) not null, value integer(10) not null);

create table refurbishment (ref char(25) not null, event_code char(4) not null, date date not null, content char(100) not null);

create table lookup (column_name char(30) not null, code char(5) not null,   name char(30) not null, description char(100));

create table monitored(m_id char(25) not null, m_code char(4) not null, datetime datetime not null, m_item char(8) not null, value decimal(12,3));

create table pv_system (ref CHAR(20) not null, building_ref char(20), name char(20) not null,   installer char(20), pannel_ref char(12) not null, num_pannels integer(3) , tilt_surface decimal(7,2), orientation decimal(7,2), tracking_type char(4), inverter_ref char(12), heat_recover_ref char(12), electrolyser_ref char(12));

create table pv_pannel (pannel_ref char(12) not null, name char(20) not null, manufacturer char(20), cell_type char(4) not null, open_circuit_voltage decimal(7,2) not null, short_circuit_current decimal(7,2) not null, max_power_voltage decimal(7,2) not null, max_power_current decimal(7,2) not null, temp_at_stc decimal(7,2) not null, ins_at_stc decimal(7,2) not null, no_of_series_connected_cells integer(4) not null, no_of_parallel_branches integer(4) not null, width decimal(7,2) not null, height decimal(7,2) not null, nominal_peak_power decimal(7,2) not null);

create table heat_recovery (heat_recover_ref char(12)not null, name char(20) not null, gap_width decimal(7,2) not null, facet_width decimal(7,2) not null ,facet_length

```
decimal(7,2) not null,  emissivity_wall decimal(7,2), emissivity_pv decimal(7,2),
convection_type char(4),  flow_rate decimal(7,2));

create table inverter ( inverter_ref char(12) not null, name char(20) not null,
manufacturer char(20), rated_power decimal(7,2) not null, efficiency decimal(7,2)
);

alter ignore table pv_system ADD primary key (ref);

alter ignore table pv_system add index pv_index( building_ref, installer, ref);

alter ignore table pv_pannel ADD primary key (pannel_ref);

alter ignore table pv_pannel add index pannel_index( manufacturer, cell_type,
pannel_ref);

alter ignore table heat_recovery ADD primary key (heat_recover_ref);

alter ignore table heat_recovery add index heat_recover_index( convection_type,
heat_recover_ref);

alter ignore table inverter ADD primary key (inverter_ref);

alter ignore table inverter add index inverter_index( manufacturer, inverter_ref);

alter ignore table entity ADD primary key (ref);

alter ignore table entity add index entity_index( data_type, entity_type,  ref);

alter ignore table building ADD primary key (ref);

alter ignore table building add index building_index( building_ref, ref);

alter ignore table energy add index energy_index (ref, fuel_type, r_type, meter_id );
```

alter ignore table energy add unique(ref, fuel_type, meter_id, r_type, to_datetime);

alter ignore table indoor_climate add index indoor_climate_index(ic_code, ic_item,datetime,ref);

alter ignore table indoor_climate add unique(ref, ic_code, datetime, ic_item);

alter ignore table climate add index climate_index(climate_site, climate_code, item);

alter ignore table climate add unique(climate_site, climate_code, datetime,item);

alter ignore table climate_site add index climate_index(climate_site, coord_code, item);

alter ignore table climate_site add unique(climate_site, coord_code, datetime,item);

alter ignore table climate_espr add index climate_index(climate_site);

alter ignore table climate_espr add unique(climate_site, datetime);

alter ignore table deg_days add index deg_days_index(dd_code, date);

alter ignore table deg_days add unique(dd_code, type_dd, date, dd);

alter ignore table gas_emission_factors add index gas_emission_index(region_code, gas_emission_code, fuel_type);

alter ignore table gas_emission_factors add unique(region_code, gas_emission_code, date, fuel_type, gas_type);

alter ignore table operation add index operation_index(op_code, datetime, op_item, ref);

alter ignore table operation add unique(ref, op_code, datetime, op_item);

```
alter ignore table refurbishment add index refurbishment_index( ref, event_code );

alter ignore table refurbishment add unique( ref, event_code, date );

alter ignore table lookup add index code_list_index( column_name, code);

alter ignore table lookup add unique( column_name, code, name);

alter ignore table monitored add index monitored_index( m_id, datetime);

alter ignore table monitored add unique( m_id, datetime, m_item);
```

B.2 Create User accounts

```
INSERT INTO USER (Host,user,password, Select_priv, insert_priv,  update_priv,
    delete_priv, create_priv, drop_priv, reload_priv,shutdown_priv,process_priv,
    file_priv,grant_priv,references_priv, index_priv, alter_priv)   VALUES ( '%','user',
    PASSWORD('user'),   'y','y','y','n','n','n','n','n','n','n','n','n','n','n');

FLUSH PRIVILEGES  ;

INSERT INTO USER (Host,user,password, Select_priv, insert_priv, update_priv,
    delete_priv, create_priv, drop_priv, reload_priv, shutdown_priv, process_priv,
    file_priv,grant_priv, references_priv,  index_priv, alter_priv)  VALUES
    ('%','manager',PASSWORD('manager'), 'y','y','y','y','y','y','y','n','n','n','n','n','y','y');

FLUSH PRIVILEGES  ;
```

B.3 Importing data

1) MySQL command to import data:

```
LOAD DATA INFILE 'building.txt' REPLACE INTO TABLE building FIELDS
    TERMINATED BY '\t'  LINES TERMINATED BY '\n';

LOAD DATA INFILE 'energy.txt' REPLACE INTO TABLE energy FIELDS
    TERMINATED BY '\t'  LINES TERMINATED BY '\n';
```

2) Equivalently, an example of Unix script to run MySQL's own program for importing data :

```
#!/bin/sh

mysqlimport  --host 10.1.11.9 -u min -p training deg_days.txt --replace  --fields-
    terminated-by='\t' --lines-terminated-by='\n'
```

B.4 SQL scripts for the case study of Highland Council

Automatic data update linking property database in Planning Department.

The SQL update code used within MS Access:

```
UPDATE Property INNER JOIN [Entrak BUILDING] ON Property.ENERGY_REF
    [Entrak BUILDING].[REF,C,10] SET [Entrak BUILDING].[GIS_XREF,C,8]
    =DLookUp("[Easting]","[GridTiles]","[GridTile] = '" & Left([grid ref],2) &"'") &
    Mid([grid ref],3,5), [Entrak BUILDING].[GIS_YREF,C,8]
    =DLookUp("[Northing]","[GridTiles]","[GridTile] = '" & Left([grid ref],2) &"'") &
    Mid([grid ref],8,5)WHERE (((Property.HC_REF) Like "HC*"));
```

The SQL update code used within MS Access is as follows.

The data set for all fuel types in 1998.

```
SELECT building.ref, type_entity, sort_code_1, sort_code_2, sum(tot), ht_area,
    sum(tot/ht_area) FROM highland.energy LEFT JOIN highland.building  ON
```

highland.energy.ref = highland.building.ref WHERE to_date > '1997-12-16' AND to_date <'1999-01-15' AND highland.building.type_entity GROUP BY building.ref;

B.5 SQL scripts the case study of Strathclyde University

Data aspect table for 3D visualisation analysis:

```
SELECT building.ref, building.name, entity_type, district, sum(tot)/450000,
    ht_vol/4500, sum(tot/ht_vol)/1200,  SUM(tot), ht_vol, sum(tot/ht_vol) FROM
    energy LEFT JOIN building ON energy.ref = building.ref  WHERE  to_date >
    '1999-01-15' AND to_date <'2000-01-15' AND fueltype = '2' and ht_vol > 0
    GROUP BY building.ref
```

Heat Power ratios based on annual energy use:

```
SELECT p1.ref,building.type_entity, p1.fueltype,  sum(p1.tot),p2.fueltype,
    sum(p2.tot), sum(p1.tot)/sum(p2.tot) FROM energy as p1,   energy as p2 , building
    building WHERE p1.ref_ref=p2.ref_ref and p1.fueltype ='1' and p2.fueltype='2'
    and p1.to_date >'2001-01-01' and p1.to_date <='2002-05-01' and
    p1.ref=building.ref  group by p1.ref;
```

Heat Power ratio of a building (e.g. Murray Hall)

```
select p1.ref, p1.to_date, p1.fueltype,  p1.tot ,p2.fueltype,  p2.tot , p1.tot/p2.tot  from
    energy as p1,   energy as p2 where p1.ref_ref=p2.ref_ref and p1.to_date=p2.to_date
    and p1.fueltype ='1' and p2.fueltype='2' and p1.to_date >'2000-01-01' and
    p1.to_date <='2001-07-15'  and p1.ref='Murray Hall' order by p1.to_date ;
```

Appendix C. Data Code Listing of the EnTrak Databases for the Case Studies.

C.1 Highland Region

column_name	code	name
climate_site	1	Charleston - Inverness
climate_site	2	Farr - Bettyhill
climate_site	4	Fort William
climate_site	3	Gairloch - Ross
climate_site	5	Kinussie - Speyside
climate_site	6	Skye - Portree
climate_site	7	Wick - Caithness
dd_code	TV	Thames Valley Heating 15.5
dd_code	SE	South Eastern Heating 15.5
dd_code	S	Southern Heating 15.5
dd_code	SW	South Western Heating 15.5
dd_code	SV	Severn Valley Heating 15.5
dd_code	M	Midland Heating 15.5
dd_code	WP	West Pennines Heating 15.5
dd_code	NW	North Western Heating 15.5
dd_code	B	Borders Heating 15.5
dd_code	NE	North Eastern Heating 15.5
dd_code	EP	East Pennines Heating 15.5
dd_code	EA	East Anglia Heating 15.5
dd_code	WS	West Scotland Heating 15.5
dd_code	ES	East Scotland Heating 15.5
dd_code	NES	North East Scotland Heating 1
dd_code	W	Wales Heating 15.5
dd_code	NI	Northern Ireland Heating 15.5

dd_code	GL	Glasgow
district	CA	Caithness
district	SU	Sutherland
district	RC	Ross & Cromarty
district	SL	Skye & Lochalsh
district	LO	Lochaber
district	IN	Inverness
district	NA	Nairn
district	BS	Badenoch & Strathspey
fuel_type	7	Burning oil
fuel_type	13	Coal
fuel_type	8	Derv
fuel_type	1	Electricity
fuel_type	2	Gas
fuel_type	6	Gas-oil 35 sec
fuel_type	14	Kerosene
fuel_type	9	LPG
fuel_type	16	LPG Cylinders
fuel_type	3	Oil - 290 sec
fuel_type	4	Oil - 950 sec
fuel_type	5	Oil - 3500 sec
fuel_type	12	Petrol
fuel_type	10	Propane
fuel_type	17	Sewerage
fuel_type	15	Telecom
fuel_type	11	Water
operator	MO	Mobil
operator	SG	Scottish Gas
operator	TC	Transco

operator	BP	BP
operator	SH	Shell
operator	SP	Scottish Power
operator	HE	Hydro Electric
origin_data	SS	Supply Side (simulated)
origin_data	SR	Supply Side (real)
origin_data	DS	Demand Side (simulated)
origin_data	DR	Demand Side (real)
r_type	A	Actual
r_type	C	Customer
r_type	E	Estimated
r_type	H	HRC reading
r_type	N	Normal
sort_code_1	6	
sort_code_1	1	Accommodation
sort_code_1	M	Assessor
sort_code_1	F	Chief Executive
sort_code_1	N	Childrens Reporter
sort_code_1	50	Community Education
sort_code_1	E	Cultural Services
sort_code_1	R	Economic Development
sort_code_1	A	Education
sort_code_1	I	Finance
sort_code_1	P	Fire
sort_code_1	24	Housing
sort_code_1	G	Law & Administration
sort_code_1	S	Multi Occupancy
sort_code_1	Q	Non HRC
sort_code_1	D	NOSWA

sort_code_1	H	Personnel Services
sort_code_1	J	Planning
sort_code_1	O	Police
sort_code_1	K	Property Services
sort_code_1	L	Protective Services
sort_code_1	RE	Registrar
sort_code_1	B	Social Services
sort_code_1	C	Transport Services
sort_code_2	L	Highlands & Islands Fire Briga
sort_code_2	9	Leased to occupier
sort_code_2	K	Northern Constabulary
sort_code_2	8	NOSWA
sort_code_2	6	Private
sort_code_2	A	The Highland Council
supplier	MO	Mobil
supplier	SG	Scottish Gas
supplier	TC	Transco
supplier	BP	BP
supplier	SH	Shell
supplier	SP	Scottish Power
supplier	HE	Hydro Electric
tar_id	81	Catering
tar_id	0	Domestic.......... standard
tar_id	1	Domestic.......... standard mo
tar_id	2	Domestic.......... economy (wh
tar_id	3	Domestic.......... economy mod
tar_id	11	General........... evening/wee
tar_id	12	General........... evening/wee
tar_id	13	General........... evening/wee

tar_id	14	General.......... standard (2
tar_id	15	General.......... standard (3
tar_id	16	General.......... standard (4
tar_id	17	General.......... economy (2
tar_id	18	General.......... economy (3
tar_id	19	General.......... economy (4
tar_id	20	Farm............. standard (2
tar_id	21	Farm............. standard (2
tar_id	22	Farm............. standard (3
tar_id	23	Farm............. standard (3
tar_id	24	Farm............. standard (4
tar_id	25	Farm............. standard (4
tar_id	30	Farm............. economy (2
tar_id	31	Farm............. economy (2
tar_id	32	Farm............. economy (3
tar_id	33	Farm............. economy (3
tar_id	34	Farm............. economy (4
tar_id	35	Farm............. economy (4
tar_id	40	Industrial........ high volt.
tar_id	41	Industrial........ high volt.
tar_id	42	Industrial........ high volt.
tar_id	43	Industrial........ medium volt
tar_id	44	Industrial........ medium volt
tar_id	45	Industrial........ medium volt
tar_id	54	Maximum Demand.... high volt
tar_id	55	Maximum Demand.... medium volt
tar_id		Maximum Demand.... schedule 1
tar_id	72	

tar_id	73	Maximum Demand.... schedule 1
tar_id	74	Maximum Demand.... schedule 2
tar_id	75	Maximum Demand.... schedule 2
tar_id	76	Maximum Demand.... schedule 2
tar_id	60	Restricted hours.. high volt
tar_id	61	Restricted hours.. medium volt
tar_id	62	Restricted hours.. high volt
tar_id	63	Restricted hours.. medium volt
tar_id	64	Restricted hours.. high volt
tar_id	65	Restricted hours.. medium volt
tar_id	66	Restricted hours.. high volt
tar_id	67	Restricted hours.. medium volt
tar_id	80	*Crop drying
tar_id	90	*Construction
tar_id	92	*Public Lighting
tar_id	95	*Other
entity_type	35	Adult Training Centre
entity_type	36	Air Strip
entity_type	23	Art Gallery
entity_type	79	Bus Station
entity_type	40	Car Park
entity_type	57	Caravan Site
entity_type	75	Changing Rooms
entity_type	45	Chlorination Plant
entity_type	73	Clinic
entity_type	58	Clock Tower
entity_type	76	Clubhouse
entity_type	41	College
entity_type	44	Community Centre

entity_type	17	Computer Centre
entity_type	74	Courthouse
entity_type	55	Crematorium
entity_type	48	Day Care Centre
entity_type	53	Depot
entity_type	64	Factory Unit
entity_type	25	Factory, no process < 2000 m
entity_type	24	Factory, no process > 2000 m2
entity_type	19	Fire Station - Retained
entity_type	59	Fountain
entity_type	39	Garage
entity_type	77	Grandstand
entity_type	68	Greenhouse
entity_type	52	Hall
entity_type	27	Hanger
entity_type	71	Harbour
entity_type	43	Hostel
entity_type	49	House
entity_type	54	House - Janitor
entity_type	65	Information Centre
entity_type	28	Kitchen (Cooking)
entity_type	29	Kitchen (Non-cooking)
entity_type	21	Library
entity_type	60	Mortuary
entity_type	22	Museum
entity_type	1	Nursery School
entity_type	14	Offices, air conditioned < 20
entity_type	13	Offices, air conditioned > 20
entity_type	16	Offices, nat. ventilated < 20

entity_type	15	Offices, nat. ventilated > 20
entity_type	30	Outdoor Centre
entity_type	78	Pavilion
entity_type	42	Pier
entity_type	18	Police Station
entity_type	51	Primary School & Community Ctr
entity_type	2	Primary School, no pool
entity_type	3	Primary School, with pool
entity_type	61	Public Convenience
entity_type	46	Radio Station
entity_type	34	Reservoir
entity_type	32	Residential Home - Children
entity_type	31	Residential Home - Elderly
entity_type	63	Retail Outlet
entity_type	4	Secondary School, no pool
entity_type	5	Secondary School, with pool
entity_type	6	Secondary School, with sports
entity_type	50	Secondary School/Community Ctr
entity_type	56	Service Point
entity_type	62	Serviced Site
entity_type	33	Sewage Treatment Works
entity_type	69	Slaughterhouse
entity_type	7	Special School, non-residenti
entity_type	8	Special School, residential
entity_type	11	Sports Centre, no pool
entity_type	10	Sports Centre, with pool
entity_type	12	Sports Club

entity_type	66	Sports Pavilion
entity_type	47	Store
entity_type	9	Swimming Pool
entity_type	20	Transport Depot
entity_type	26	Warehouse
entity_type	72	Wash-bed
entity_type	37	Water Pumping Station
entity_type	70	Workshop
entity_type	67	Yard
entity_type	38	Youth Centre

C.2 Springburn Ward, Glasgow

Column name	Code	Name
district	34	WARD 34
district	36	WARD 36
entity_type	AG	AGED COUPLES FLAT - GROUND
entity_type	AU	AGED COUPLES FLAT - UPPER
entity_type	BW	BANGALOW
entity_type	DG	DECK ACCESS - GROUND
entity_type	DU	DECK ACCESS - UPPER
entity_type	DV	DETACHED VILLA
entity_type	E1	END-TERRACE - 1 STOREY
entity_type	E3	END-TERRACE - 3 STOREY
entity_type	ET	END TERRACE - 2 STOREY
entity_type	LF	LOWER FLAT
entity_type	LU	LOCK UP
entity_type	M1	MID-TERRACE - 1 STOREY
entity_type	M3	MID-TERRACE - 3 STOREY
entity_type	MG	MULTI-STOREY - GROUND
entity_type	MM	MULTI-STOREY - 1ST & ABOVE
entity_type	MT	MID-TERRACE - 2 STOREY
entity_type	MU	MULTI - STOREY - 5TH & ABOVE
entity_type	NT	NON TENNEMENT
entity_type	PA	PERNAMENT ALLUMINIUM
entity_type	SD	SEMI - DETACHED
entity_type	SS	SHELTERED HOUSING
entity_type	TE	TENEMENT
entity_type	TG	TENNEMENT - GROUND
entity_type	TU	TENNEMENT - UPPER
entity_type	UF	UPPER FLAT

sort_code_1	11	GDC housing (101)
sort_code_1	12	GDC estates
sort_code_1	13	GDC parks
sort_code_1	14	GDC halls
sort_code_1	15	GDC cleansing
sort_code_1	16	GDC markets
sort_code_1	17	GDC museums
sort_code_1	18	Transferred to SSHA
sort_code_1	21	SRC estates
sort_code_1	22	SRC education
sort_code_1	23	SRC police
sort_code_1	24	SRC social work
sort_code_1	31	Factored. Not owned by GDC (3
sort_code_1	32	Sold
sort_code_1	33	Homestead
sort_code_1	34	Rented by GDC (304)
sort_code_1	35	Acquired properties
sort_code_1	36	Tenant co-op (306)
sort_code_1	37	Acquired properties - area off
sort_code_1	38	PAR value co-op
sort_code_1	39	GDC lockups (309)
sort_code_1	61	Private properties (601)
sort_code_1	62	Non-vr private properties
sort_code_1	63	IFS shemes private properties
sort_code_1	64	Outwith vr private properties
sort_code_2	1	1 Apartment
sort_code_2	2	2 Apartment
sort_code_2	3	3 Apartment

sort_code_2	4	4 Apartment
sort_code_2	5	5 Apartment
sort_code_2	6	6 Apartment
sort_code_2	7	7 Apartment
sort_code_2	99	unknown

Appendix D. List of Entities and Meter Reading Points within the University of Strathclyde

D.1 List of entities on the John Anderson campus.

Type	Entity name	Built year	Floors	Floor area
Academic	Architecture	1967	3	5058
Academic	Colville	1967	9	13229
Academic	Curran	1981	6	27447
Academic	Graham Hills	1962	9	20916
Academic	Henry Dyer	1969	3	2629
Academic	James Weir	1957	8	20787
Academic	John Anderson	1971	8	12787
Academic	Livingstone Tower	1965	16	15906
Academic	McCance	1963	4	7458
Academic	Royal College	1911	7	40732
Academic	SGBS	1992	8	6763
Academic	Sir William Duncan	1976	7	5421
Academic	Stenhouse	1972		4863
Academic	Thomas Graham	1964	9	12997
Academic	Wolfson	1971	6	4225
Office	Collins	1972	2	1606
Office	Estates Management			
Office	University Centre	1975	4	5248
Office	Village			
Research	EAC Room 4.16			
Research	Engineering Application Centre			
Residence	Baird Hall	1937	9	7516
Residence	Birkbeck Court	1972	4	6720

Residence	Chancellors Hall	1992	7	4900
Residence	Forbes Hall	1987	4	2880
Residence	Garnet Hall	1987	4	2769
Residence	James Blyth Court		5	4046
Residence	James Goold Hall	1997	7	3606
Residence	James Young Hall		5	1870
Residence	Murray Hall	1984	4	1194
Residence	Thomas Campbell Court		5	2090
Service	Barony Hall	1890	2	1389
Service	Chaplaincy	1908	3	1976
Service	Creche			
Service	Greenhouses Ross Priory			
Service	John Smiths Bookshop			
Service	Lord Todd	1995	2	880
Service	Mr McCallum			
service	Pool			
Service	Ramshorn	1826	2	1198
Service	Stepps Pavilions			1133
Service	Students Union	1959	6	5208
Service	Todd Centre	1975	5	4617
Service	Turnbull	1971	9	3333

D.2 List of meter reading points

Entity name	Fuel type	meter_id
Architecture	Electricity	ARCHITEC.E
Architecture	Gas	ARCHITECT.
Baird Hall	Gas	BAIRD.1
Baird Hall	Gas	BAIRD.2

Barony Hall	Gas	BARONY
Barony Hall	Electricity	BARONY.1
Birkbeck Court	Gas	BIRKBECK
Birkbeck Court	Electricity	BIRKBECK 2
Campus 1	Electricity	SUB 2.
Chancellors Hall	Gas	CHANCELLOR
Chancellors Hall	Electricity	CHANCELOR1
Chancellors Hall	Electricity	CHANCELOR2
Chancellors Hall	Electricity	CHANCELOR3
Chaplaincy	Electricity	STP/1
Collins	Electricity	CO/1
Collins	Gas	COLLINS
Colville	Gas	COLVILLE
Colville	Gas	COLVILLE.A
Colville	Electricity	COLVILLE.E
Creche	Gas	CRECHE
Curran	Gas	CURRAN
Curran	Electricity	CURRAN.2
Curran	Electricity	CURRAN.3
Curran	Electricity	CURRAN.4
Curran	Gas	HOTEL SCHL
EAC	Gas	E.A.C.
EAC	Electricity	E.A.C.1
EAC	Electricity	E.A.C.3
EAC	Electricity	E.A.C.4
EAC	Electricity	E.A.C.5
EAC	Gas	INCUBATORS
EAC Room 4.16	Electricity	E.A.C.2
Estates Manageme	Gas	EST.MAN.

Estates Manageme	Electricity	EST.MAN.1
Forbes Hall	Electricity	FORBES.1
Forbes Hall	Gas	FORBES.A
Forbes Hall	Gas	FORBES.B
Forbes Hall	Gas	FORBES.C
Gardeners Jordan	Gas	J/GARDENS
Garnet Hall	Electricity	GARNET.1
Garnet Hall	Electricity	GARNET.2
Garnet Hall	Electricity	GARNET.3
Garnet Hall	Gas	GARNET.A
Garnet Hall	Gas	GARNET.B
Garnet Hall	Gas	
Graham Hills	Electricity	GH/1
Graham Hills	Electricity	GH/3
Graham Hills	Gas	GRAH.HILLS
Henry Dyer	Gas	DYER
Henry Dyer	Electricity	DYER.E
James Blyth Cour	Electricity	BLYTH.1
	Electricity	BLYTH.2
James Blyth Cour	Electricity	
James Blyth Cour	Electricity	BLYTH.4
James Blyth Cour	Electricity	BLYTH.5
James Blyth Cour	Electricity	BLYTH.6
James Blyth Cour	Electricity	BLYTH.7
James Blyth Cour	Gas	BLYTH.EF
James Blyth Cour	Gas	BLYTH.GHJ
James Goold Hall	Electricity	GOOLD.E
James Goold Hall	Gas	GOOLD.G
James Weir	Electricity	TG/W/1

James Weir	Gas	WEIR
James Young Hall	Gas	J.YOUNG
James Young Hall	Electricity	J.YOUNG.1
James Young Hall	Electricity	J.YOUNG.2
Janitor Jordanhi	Gas	J/JANITOR
John Anderson	Gas	ANDERSON.A
John Anderson	Electricity	ANDERSON.E
John Anderson	Gas	ANDERSON.H
John Anderson	Gas	ANDERSON/D
John Smiths Book	Electricity	J.S.BOOK.1
Kerr	Gas	J/KERR
Livingstone Towe	Gas	LIV.TOWER
Livingstone Towe	Electricity	LT/1
Livingstone Towe	Electricity	LT/2
Lodge	Gas	
Lord Todd	Gas	LORD TODD
Lord Todd	Electricity	LORD TODD1
Lymehurst	Gas	J/LYMH
McCance	Gas	MC.CANCE
McCance	Electricity	MCC/1
McCance	Electricity	
Murray Hall	Gas	MURRAY
Murray Hall	Electricity	MURRAY.1
Pool	Gas	SWIM/POOL
Ramshorn	Gas	DRAMA CENT
Ramshorn	Electricity	RAMSHORN1
Royal College	Gas	LEVEL3 RCB
Royal College	Gas	R.COLLEGE

Royal College	Electricity	RCB/NW
Royal College	Electricity	RCB/SE
Royal College	Electricity	RCB/SW
SGBS	Gas	S.G.B.S.
SGBS	Electricity	S.G.B.S.1
Sir William Dunc	Gas	S.W.D.
Sir William Dunc	Electricity	S.W.D.1
Sir William Dunc	Electricity	S.W.D.2
	Gas	S.W.D.DOM
Smith	Gas	J/SMITH
Stepps Pavilions	Gas	STEPPS
Students Union	Electricity	S/UNION.1
Students Union	Electricity	S/UNION.3
Students Union	Electricity	S/UNION.4
Students Union	Gas	STUD/UNION
Thomas Campbell	Electricity	TH/CAMB.1
Thomas Campbell	Electricity	TH/CAMB.2
Thomas Campbell	Electricity	TH/CAMB.3
Thomas Campbell	Electricity	TH/CAMB.4
Thomas Campbell	Gas	TH/CAMB.AB
Thomas Campbell	Gas	TH/CAMB.CD
Thomas Graham		GRAHAM
Thomas Graham	Electricity	TG/1000
Todd Centre	Gas	TODDCENT/N
Turnbull		TU/1
Turnbull	Gas	TURNBULL
University Centr	Gas	MARTHA ST.
University Centr	Gas	U/CENTRE.
University Centr	Electricity	U/CENTRE.1

University Centr	Electricity	U/CENTRE.2
	Electricity	U/CENTRE.3
University Centr	Electricity	U/CENTRE.4
University Centr	Electricity	U/CENTRE.E
Village	Gas	VILLAGE
Wolfson	Gas	WOLFSON

Appendix E. Registering Images to a GIS Map

The Tag Image File Format (TIFF) has widespread use in the desktop publishing world. It serves as an interface to several scanners and graphic arts packages. TIFF supports black-and-white, grayscale, pseudocolor and true color images, all of which can be stored in a compressed or uncompressed format. The TIFF image formats store the geo-referencing information in a separate ASCII file. This file is generally referred to as the world file, since it contains the real-world transformation information used by the image. World files can be created with any editor.

World files use the same name as the image but with a "w" appended. For workspaces that must adhere to the 8.3 naming convention, the first and third characters of the image file's suffix and a final 'w' are used for the world file suffix. Therefore, if mytown.tif were in a an 8.3 format workspace, the world file would be mytown.tfw. If redlands.rlc was in 8.3 format workspace, its world file would be redlands.rcw. An example world file is given by

```
tfw
20.17541308822119
0.00000000000000
0.00000000000000
-20.17541308822119
424178.11472601280548
4313415.90726399607956
```

When this file is present, a GIS package such as ArcView performs the image-to-world transformation. This transformation is a six-parameter affine transformation in the form of:

$x1 = Ax + By + C$

$y1 = Dx + Ey + F$

where

x1 = the calculated x-coordinate of the pixel on the map

y1 = the calculated y-coordinate of the pixel on the map

x = the column number of a pixel in the image

y = row number of a pixel in the image

A = x-scale; dimension of a pixel in map units in x direction

B, D = rotation terms

C, F = translation terms; x,y map coordinates of the center of the upper-left pixel

E = negative of y-scale; dimension of a pixel in map units in y direction

Note that the y-scale (E) is negative because the origins of an image and a geographic coordinate system are different. The origin of an image is located in the upper-left corner, whereas the origin of the map coordinate system is located in the lower-left corner. Row values in the image increase from the origin downward, while y-coordinate values in the map increase from the origin upward.

The transformation parameters are stored in the world file in this order:

20.17541308822119 - A
0.00000000000000 - D
0.00000000000000 - B
-20.17541308822119 – E
424178.11472601280548 - C
4313415.90726399607956 – F

Appendix F. Web-based e-resource Sharing System

The implementation of the Web-based energy information sharing systems is based on a confederation of SQL databases, with Java Applets performing the maintenance and retrieval tasks. Authorised members (as information contributors) use the Applet to make postings to the appropriate database. Each upload spawns the retrieval Applet, which updates the corresponding Web page. The essential feature of the facility is that the history of document postings is made known to members, who may then download documents as required. Figure F-1 illustrates the system structure and the components of the prototype of the Web-based energy information system. The role of each component is as follows.

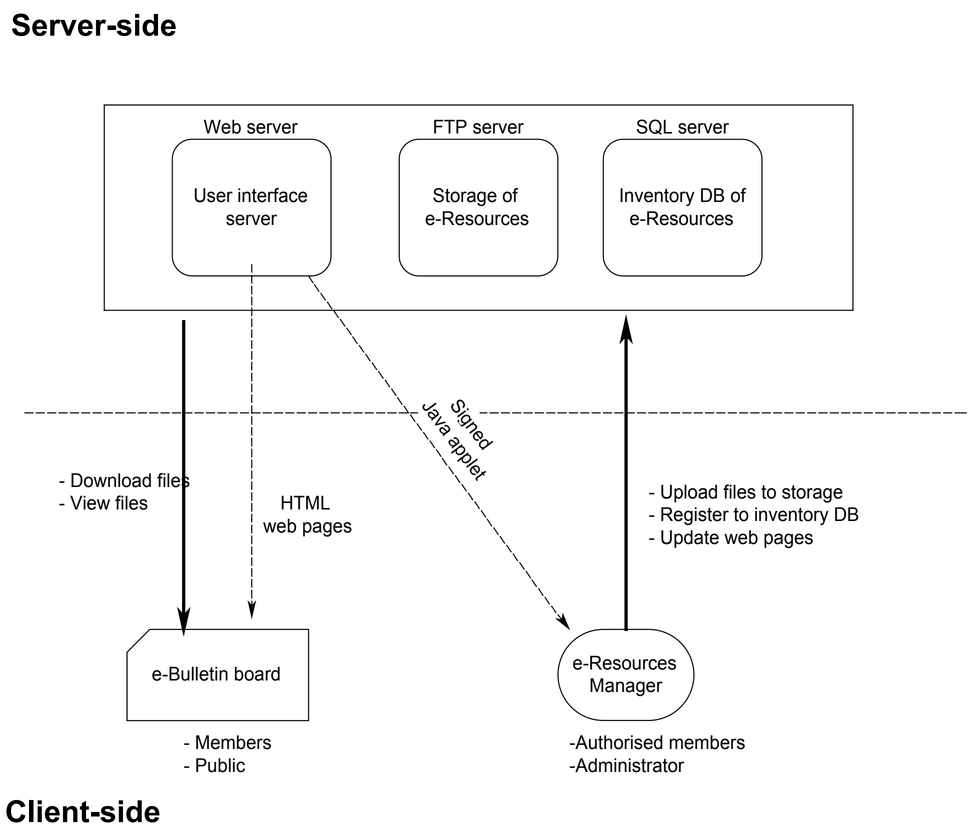

Figure F-1 Figure F-1 System structure and components of the prototype Web-based energy information system.

e-Resource manager. This manages the server side system remotely through FTP communication. When this manager posts a new e-resources to storage on the server side, it simultaneously registers a reference to the new e-resources (e.g. creator, time stamp, description, location of e-resources, access level, priority etc.) in the inventory database. Once uploaded and registered, the e-resource manager updates the HTML pages in the Web server. Since the e-resources manager remotely controls the systems at both the server-side and client-side, it must be operated by authenticated people. In this system, password and public key are exploited for authentication. The e-resources manager is implemented with a signed Java Applet, which is embedded in a main Web page (see Figure F-2). Figure F-3 shows the interface of a signed Java Applet.

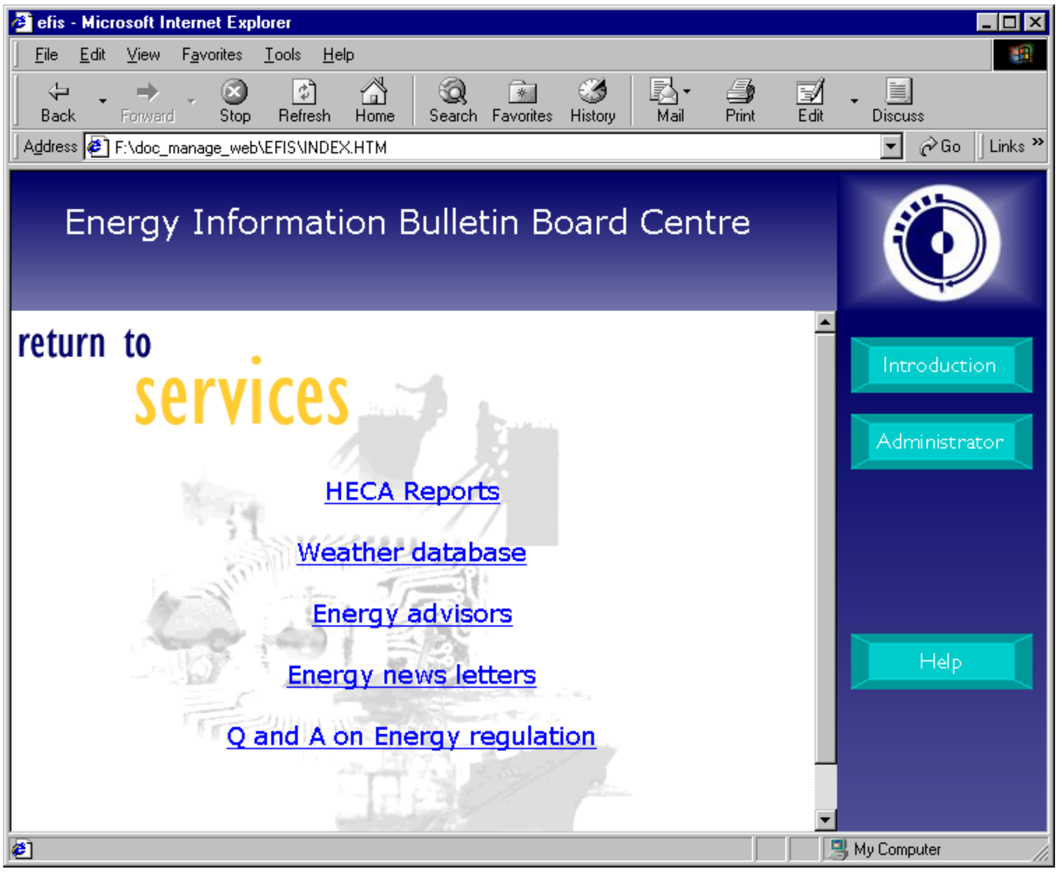

Figure F-2 An example of a main page.

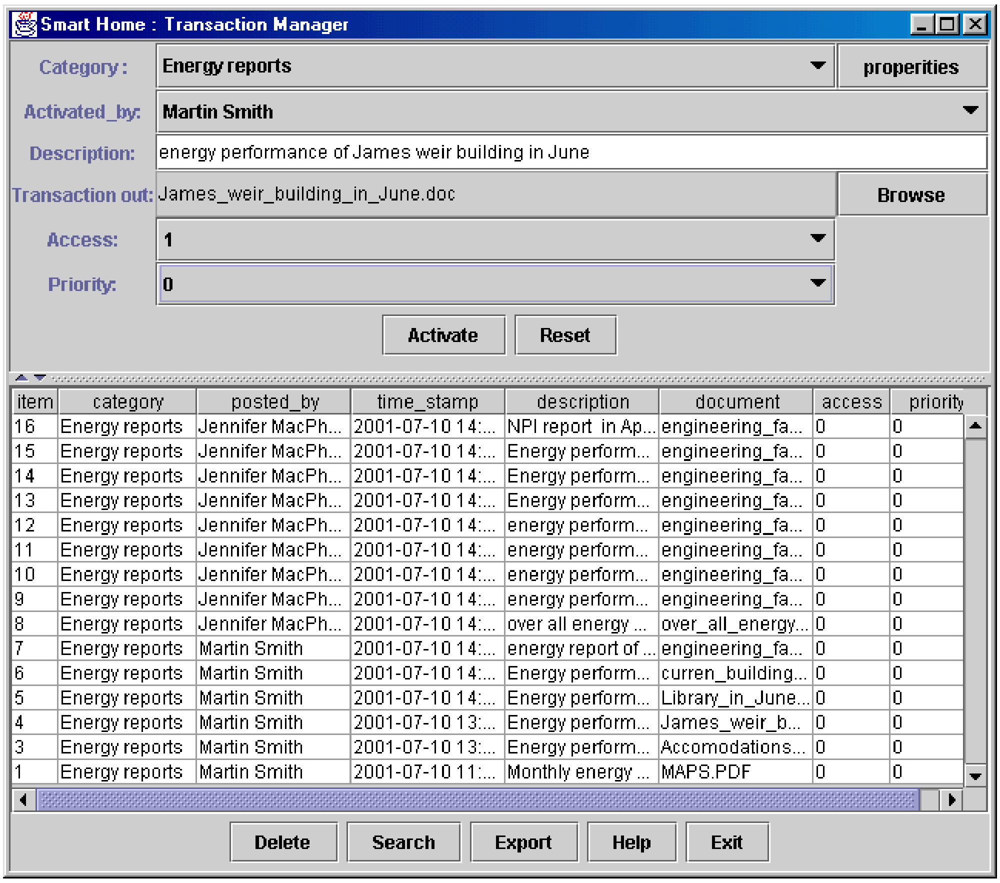

Figure F-3 The interface of a signed Java Applet.

e-Bulletin board. The e-Bulletin board is a user interface, which allows people (members of a partnership or the public) to browse the list of available e-Resources at the server-side and download them through HTTP as required. The e-Bulletin board is implemented in an HTML page. Figure F-4 gives an example corresponding to the main page of Figure F-2.

Inventory database. This administers the reference information of e-Resources sent by the e-Resource manager. A SQL server is used for the database management.

Storage of e-Resources. e-resources posted from the e-Resources manager are stored in directories managed by a FTP server. The FTP server manages the access level of the directories, classifying them as open-to-public and members-only. The FTP communication is also exploited by the e-Resources manager to update the contents of HTML pages used by the Web server on the same server side.

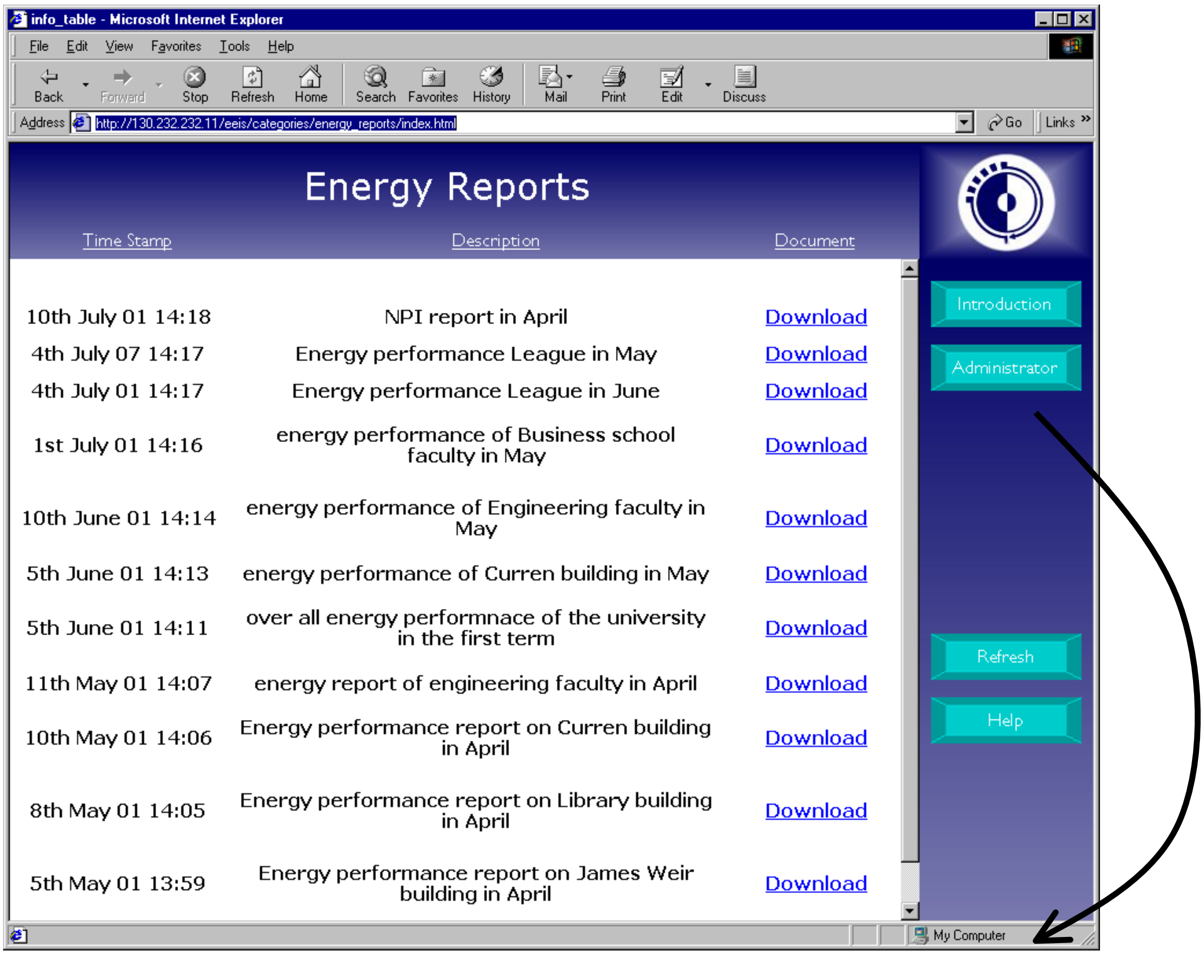

Figure F-4 An example of e-Bulletin boards page.

Web server. This provides the Web pages of the e-Bulletin board and a e-resource manager Java Applet.

In order to protect e-resources from intrusion on the server-side, an administrator using the e-resource manager requires a username and a password to verify his/her identity. These data are identical to those used on the SQL server and FTP server since the e-resource manager operates both sides. In addition to basic authentication, an electronic key is also required to run the e-resources manager Java Applet. The electronic key is required to reinforce user authentication because the user password may be intercepted during transmission.

Here, the electronic key authentication has been established with Java security tools such as ‘keytool’, ‘jarsigner’ and ‘policytool’. The administrator must possess a Java policy file, conventionally named ‘.java.policy’, which contains the information on the security policy for the e-resources manager Java Applet. Without the Java policy file, the Java Applet cannot access local files on the client side. The access to the Web site itself can be controlled by the Web server’s access configuration. The Web server can give access permission to either the host whose IP address was registered in the Web server or the users who have authentication.

Appendix G. Planning Factors for Wind Power Development in Caithness

G.1 Environment and Policy Factors

	Sensitive (score 3)	Intermediate (scoree 2)	Possible (score 1)
Key bird distribution	All bird areas	Not assigned[1]	All non-bird areas
Landscape assessment and character type	Land types 3, 5 and 7	Landscape types 2, 4 and 8	Landscapes 1, 1b and 6
Landscape designations	Areas of great landscape values and designated landscapes	Not assigned	The rest
Nature conservation designations	Sites of special scientific interest	Not assigned	The rest
Archaeological significance	Areas of exceptional archaeological interest	Areas of above average archaeological interest	The rest
Caution areas(airport and masts)	Not assigned	Caution areas	The rest
Microwave link corridors	Within 200m of links	Not assigned	The rest

[1] Indicates that no area will receive this score.

Proximity to dwelling[2]	Within 1 km of dwelling	Between 1 and 2km from a dwelling	Greater than 2 km from a dwelling
Proximity to a railway line	Not assigned	Within 2 km of a railway	The rest

G.2 Technical Factors

	Unlikely (score 3)	Likely (score 2)	Favourable (score 1)
Grid access	Greater than 15 km from a grid line	Between 5 and	Less than 5 km from a grid line
Land classification	Woodland, wetland, montane and built-up	Peatland	Rough grazings and agricultural
Vehicle access	Grater than 6 km from any road or vehicle track	Between 3 and 6 km from any road or vehicle track	Less than 3 km from any road or vehicle track

[2] Calculated using "proximity to public roads" (and hence by and large public housing) to reflect the Councils general policy that wind turbines should not be located loser than 1 km to a dwelling.