Price Risk Analysis in Electricity Supply

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Abstract

The imminent Franchise Break, the latest step in the opening up to competition of the UK Electricity Supply market, has highlighted the issues that will affect the prices which customers pay for electricity. In particular, the fluctuating wholesale price of electricity has exposed the industry to new risks and an ever-increasing need for better information and analysis.

At present, Suppliers purchase electricity wholesale from the UK market for electricity, the Pool, and sell it on to end-users, hoping to achieve a profit: there are many companies eager to become involved in this business. Since most electricity contracts between Supplier and end-user are agreed on the basis of fixed tariffs the Suppliers are exposed to significant risk. In order to quote a customer a tariff, or set of tariffs, for his future use of electricity, the Supplier needs to forecast both the customer's demand and the price of electricity in the Pool. The amount of revenue the Supplier receives from a customer depends on the actual amount and pattern of electricity that the customer consumes and the tariffs that the Supplier has agreed to charge. The cost to the Supplier of supplying this electricity depends, in part, on the actual prices of electricity in the Pool. If the Supplier's forecasts are significantly different from the actual behaviour of the customer's demand and the Pool price, the contract can perform in a highly unexpected manner. This may lead to the Supplier making no profit on a contract. In the worst case, the Supplier can lose money.

This thesis provides an original survey of risk in electrical supply contracts and includes a discussion of a number of ways to deal with it. As far as the author is aware, this is the most comprehensive study to date of the sources of risk within the supply industry and the methods that can be used to reduce it. The thesis also describes the creation of a Decision Support System (DSS), the *Electricity Sales Integrated Price and Risk Analysis System (ESIPRAS)*, which has been developed to provide a useful analytical tool for electricity Suppliers. The system helps a Supplier to price contracts with clients and aims to provide him with a clearer understanding of the level of risk each contract might represent. The author believes this is the first time a DSS has been applied to analyse risk in electricity supply contracts. The thesis includes a description of how contracts are priced. In addition, the author proposes a new metric for grading a supply contract's risk. The author argues that this new metric offers significant advantages over the traditional measure that employs load factor. The thesis concludes with a number of recommendations for further research.

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Parties wishing to use *ESIPRAS* for commercial gain must receive the express permission of the above authors as well as permission from the University of Edinburgh.

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Chapter 1 Introduction

1.1 Coming to Market

Electricity has been used to provide energy for light, heat, motive power and other applications for over a hundred years, supplying these services for domestic, commercial, industrial and institutional consumption. Within this period, electricity has been sold at tariffs usually agreed by combinations of local authorities, governments and businesses, and often set in competition with other sources of energy, notably gas. However, until recently, no major central exchange for electricity had existed, despite the fact that the economic benefits of centralised markets for trading commodities have been known throughout the last century and long before. The London Corn Exchange, for example, was formed in 1749 to facilitate efficient trading of cereals, fertilisers and animal foodstuffs. Such exchanges provide a means of not only drawing together buyers and sellers, but also help to create efficient market prices for products. These prices implicitly take into account all relevant information to produce an interpretation of their "worth" and are generated by harnessing the knowledge, information and activities of the traders. This interpretation of "worth" should take into account at least the cost of production, and the level of demand and supply to be economically sensible.

However, one drawback of this activity, if it can be so considered, is that the prices of such traded commodities respond to the continuous changes in the business environment and therefore generally fluctuate significantly. The price of cereal on the Corn Exchange, for example, may react to changes in weather conditions and/or the changes in anticipated weather conditions. This fluctuation creates uncertainty for the buyers and sellers in the market and makes it more difficult for parties to predict the return on their investments in their businesses. However, these fluctuations generally reflect all the information available to the traders and allow rational businessmen to continuously plan their activities and distribution of their resources to deal efficiently with changing circumstances. In addition, buyers and sellers can draw up contracts to make transactions more predictable for specified periods. On balance, economists have argued that it is better for economies to deal with such fluctuating markets than to lose the mechanisms that help to generate efficient, "fair" prices.

1.2 Local Monopolies with Price Restraint

Whether electricity has been sold over the years at "fair" prices is certainly debatable, as all over the world electricity networks usually began as local monopolies, run by private businesses, local or national authorities. However, price restraint came from at least two sources.

As these networks have grown bigger and more important, the tariffs the suppliers have charged have come under greater scrutiny as electricity provision has become of major economic, welfare and political importance. The pressure this has placed on Suppliers has helped to keep prices down and maintain the tremendous growth in at least the developed economies where the availability of a cheap, flexible energy supply has played an essential role.

Ironically, whilst electricity was not being traded in the markets, it was supplying the energy needed to light them. Edison sold electricity generated at his famous Pearl Street station to light Wall Street from around the 1880s. He charged consumers an amount based on how many light bulbs they bought from him. Edison and his fellow electricity pioneering entrepreneurs had competition, though, from the gas Suppliers. Gas lighting was arguably of comparable quality in those days, especially with the invention of the Welsbach mantle in 1885.

Even so, it is likely that competitive pressures to sell electricity at lower prices were less than in many other industries that were served by trading exchanges.

However, creating an exchange to trade electricity has been an ideal realised at least partially with the formation of the UK Electricity Pool, but only as recently as 1990.

1.3 A Complex Task

The governments of the past 100 years or so can be forgiven, however, for not developing a proper electricity exchange sooner. Many barriers, mainly technical and practical have stood in their way. For a start, electricity is not really like any other traded product. It cannot be effectively stored. Electricity is supplied the moment it is consumed. For engineering reasons, it is necessary for the electrical system operator to exactly match consumption with generation otherwise the system would become unstable and cease to function within the close tolerances demanded by the equipment on the system. It cannot be traded like other products where a price is set in conjunction with a specified delivery date. It would be impractical to expect a consumer to agree ahead of time a fixed pattern of use and then to exactly keep to it. Should we expect a user to turn off the washing machine or water heater, or maybe a couple of lights, just to watch the TV for an extra hour? The consumer is also not able to defer consumption like storing a bag of coal. Therefore, the flexibility to supply more or less electricity on demand is the responsibility of the electrical Suppliers.

In calculating a fair price for electricity, however, it would be sensible to take into account the effect of demand. However, if we do not know exactly what demand will be, how can this be achieved?

The approach The Pool takes is to use a best-guess forecast of demand to help set the electricity prices.

The means by which electricity is delivered is also very different to most other products. It requires the infrastructure of a huge network of wires and electricity plant.

For a trading exchange to work effectively there needs to be a number of competing parties involved in the trading mechanism. Hence, in order for there to be any semblance of competition in electricity supply, it is necessary to have a large number of distinctly owned generating plant connected to the network to supply the distributed load.

In the UK, there existed a network long before the Pool was set up. It is the National Grid, as it was named in 1926. However, in effect, it has been developing more or less since electricity supply began.

The National Grid was set up for at least two practical reasons. It connects regions of the UK with a generating surplus with regions with a power deficit. Secondly, it allows generators to supply both industrial and commercial consumption during the day and domestic and municipal use during the evening, thus allowing resources to be shared around the clock, increasing efficiency. The National Grid made technical and economic sense long before Governments thought of attempting to introduce true competition in electrical supply.

The creation of The Pool in 1990, together with the wholesale restructuring of the industry around it, harnessed the already highly developed Grid still further in an attempt to introduce competition in supply. The recent restructuring of the UK Electricity Supply Industry is described in Chapter 2, whilst the detailed workings of the Pool is described in Chapter 3.

1.4 An Issue of Technology

So, why has a competitive market such as the Pool not existed before?

This is certainly a complicated issue with no simple answer. It may be in part due to the very different political climate that existed before the Thatcherite years. It may also be in part due to the relative lack of sophistication of the UK economy as it was before the Pool was planned. The modern Electrical Supply Industry (ESI) in the UK is a highly regulated market. The regulation attempts to impose competition on an industry in which competition would not "naturally" take place. For example, there is only one network of wires to transfer electricity. In the light of this monopoly, the prices that are charged for the use of this network are subject to tight regulation. Government regulation of this nature and magnitude is a modern innovation.

However, one area that has certainly been pivotal in facilitating the Pool is Information Technology. The communication systems, control systems and their software have arguably only recently become powerful enough to simultaneously run the network, facilitate trading, predict load and to carry out the complex settlement transactions necessary to fulfil trading commitments.

1.5 A Risky New Beginning

Prior to its formation, electricity contracts between generators and customers would rarely have had more than two tariffs, one applicable during the day, and one during the night. The Pool goes further than simply attempting to generate a fair day and night tariff. It attempts to generate a fair price for electricity for each half-hour of every day, 365 days a year.

The goal of calculating fair prices that vary across the entire day certainly seems sensible. If the prices were to reflect at least the relative marginal cost of supply for each half-hour, then there are overall efficiencies to be gained. For example, consumers might shift consumption from periods of the day when electricity is relatively expensive to periods in which it is relatively cheap. Previously, there was less opportunity for consumers to make any informed choices to reduce their electricity bill. As a desirable by-product of this activity, overall network efficiency has the potential to be improved.

As discussed earlier in this introduction, the only drawback to these variable prices is that it introduces risk to the buyers and sellers. The sellers in this case are the Generators, whilst the buyers are mainly the large electricity Suppliers, who buy the electricity wholesale to sell on to their customers. Since it is still the norm for Suppliers to sell electricity at fixed tariffs, the introduction of a fluctuating market from which Suppliers purchase their electricity in turn makes their return on supply contracts less predictable and therefore risky.

Suppliers now need a method of analysing this risk. They require a method of assessing the risk of each electricity contract so that they can decide whether it is worth their while entering into an agreement, and if so at what price. A Supplier, for example, might lose money on a contract if he has set the tariffs too low and the market prices for electricity turned out to be higher than he expected during the contract.

Thus, failure of a Supplier to analyse his exposure to risk and act accordingly may lead him to suffer poor financial performance, loss or outright business failure.

1.6 Thesis Outline

This thesis describes the creation of a PC-based Decision Support System (DSS) for pricing and risk assessing electricity supply contracts. The author believes this is the first time a DSS has been applied to analysing risk in electricity supply contracts.

Computers have been employed in commerce for many years. Primarily used, in the 1960s and 70s, for simple batch processing jobs, like billing and financial reporting, where the problems that they were set to solve were highly structured and easily programmed, their application in commerce has become more sophisticated. Computers are now being employed to tackle less structured problems like credit risk evaluation and inventory control. The drivers of this revolution are not just the technologies that facilitate it, but a growing need from management to deal with more complex problems and, in the competitive environment of the 1990s, to be increasingly competitive. To be more competitive means operating more efficiently, and to operate efficiently requires better decision making; an area where computers can help.

Effective decision making within companies involved in the Electrical Supply Industry (ESI) is as critical to their success as companies in any other industry. Managers in the ESI will employ Decision Support Systems where there they are seen to provide competitive advantage e.g. in efficiently scheduling fuel delivery for generators[1].

This thesis begins, in Chapter 2, with a general introduction to the Industry. In Chapter 3, it describes the market for electricity, the Pool, in detail. These Chapters cannot be regarded as entirely original work, but they were included to aid the understanding of later chapters for readers unfamiliar with this business. Chapter 4 presents a novel survey of the nature of supply contract risk and methods that could be employed to reduce it. Very little literature exists on this subject. The author is confident that this survey represents the most significant contribution within the public domain to this discipline yet. The survey also draws on other research to provide an explanation of the term 'risk'. In Chapter 5, the thesis discusses the design and creation of the DSS, the *Electricity Sales Integrated Price and Risk Analysis System (ESIPRAS)*. This includes a description of how Suppliers price contracts. Chapter 6 describes the software in detail. Chapter 7 takes the reader through an example of the software's use. Chapter 8 discusses issues involved in the design and use of the software and in doing so proposes a new metric for grading a supply contract's risk. The author argues that this new metric has significant advantages over traditional measures that employ load factor. Chapter 8 includes a number of recommendations for further work that are also summarised in the Conclusion in Chapter 9.

Chapter 2 The Electricity Supply Industry

2.1 What does the Electricity Supply Industry do?

Simply, the Electricity Supply Industry (ESI) function is to convert fuel/primary energy into electricity and transport it to customers. Electricity storage is costly and highly inefficient so supply must always match demand. Customers have almost no scope for reserves.

The ESI can be split into four functions:

1. Generation produces electricity.

2. Transmission transports electricity in bulk to local distribution points at high voltage.

3. Distribution transports and delivers electricity to customers.

4. Supply carries out wholesale purchase for sale to end customers.

2.2 Generation

A large generating set, such as a coal station with an output of 2000MW creates enough electricity to supply Manchester. A small generating set, such as a small 300MW Combined Cycle Gas Turbine (CCGT) could supply Oxford.

Over the years, generating sets have got bigger and technology has improved. This has brought economies of scale and better efficiency respectively. A modern coal station such as Drax has a thermal efficiency of 38% and a capacity of 660 MW. Older stations used to have only capacities of 120 MW and thermal efficiencies of up to 33%. However, modern CCGT stations can have efficiencies of 55%. These stations are also cheap and quick to build, and with the present gas supply, competitive to run.

2.3 Transmission

The transmission network is made up of high voltage conductors routed across the country, mainly above ground. In England and Wales, the network consists of 275 kV and 400 kV lines. In Scotland, the network uses 400, 275 and 132 kV. Northern Ireland is served by 275 and 132 kV lines. These high voltages are used as, in the transmission of electricity, the losses are inversely related to voltage. Duplication of the network is considered uneconomic, so the bulk of electricity is transmitted through one network. Despatch of the generating sets is controlled centrally by the network authorities. The network operator, known as the Grid Operator (GO), currently the National Grid Company plc, has to ensure that:

5. Demand is met.

6. Losses are covered.

7. The stability and quality of the electricity is maintained.

2.4 Distribution

There are 15 distribution networks in the UK. 12 are run by the Regional Electricity Companies (RECs), and one each by Scottish Power, Scottish Hydro-Electric and Northern Ireland Electricity. In England and Wales, the distribution networks are fed by the transmission network at Grid Supply Points (GSPs). There are 120 GSPs. The voltage at the GSPs is stepped down to 132 kV and subsequently to 32kV, 11kV and finally reaches most customers at 240 V. Some industrial and commercial customers take electricity at 11 kV and 415 V. The highest distribution voltage in Scotland is 32 kV. There are also no parallel distribution networks, as it is also considered that this would be inefficient. However, some companies have bypassed local distribution to supply customers. Scottish Hydro-Electric plc constructed a 11kV line between a Combined Heat and Power Plant and a few nearby customers. National Power also uses a 11kV line to supply an industrial gases manufacturer.

2.5 Supply

This area of the industry purchases bulk electricity and then sells it on to business and domestic customers. Suppliers sell electricity to customers using a variety of contracts and price systems. They carry out all the administration to service these contracts, including billing and debt settlement. Figure 1 shows the general arrangement of the UK ESI.

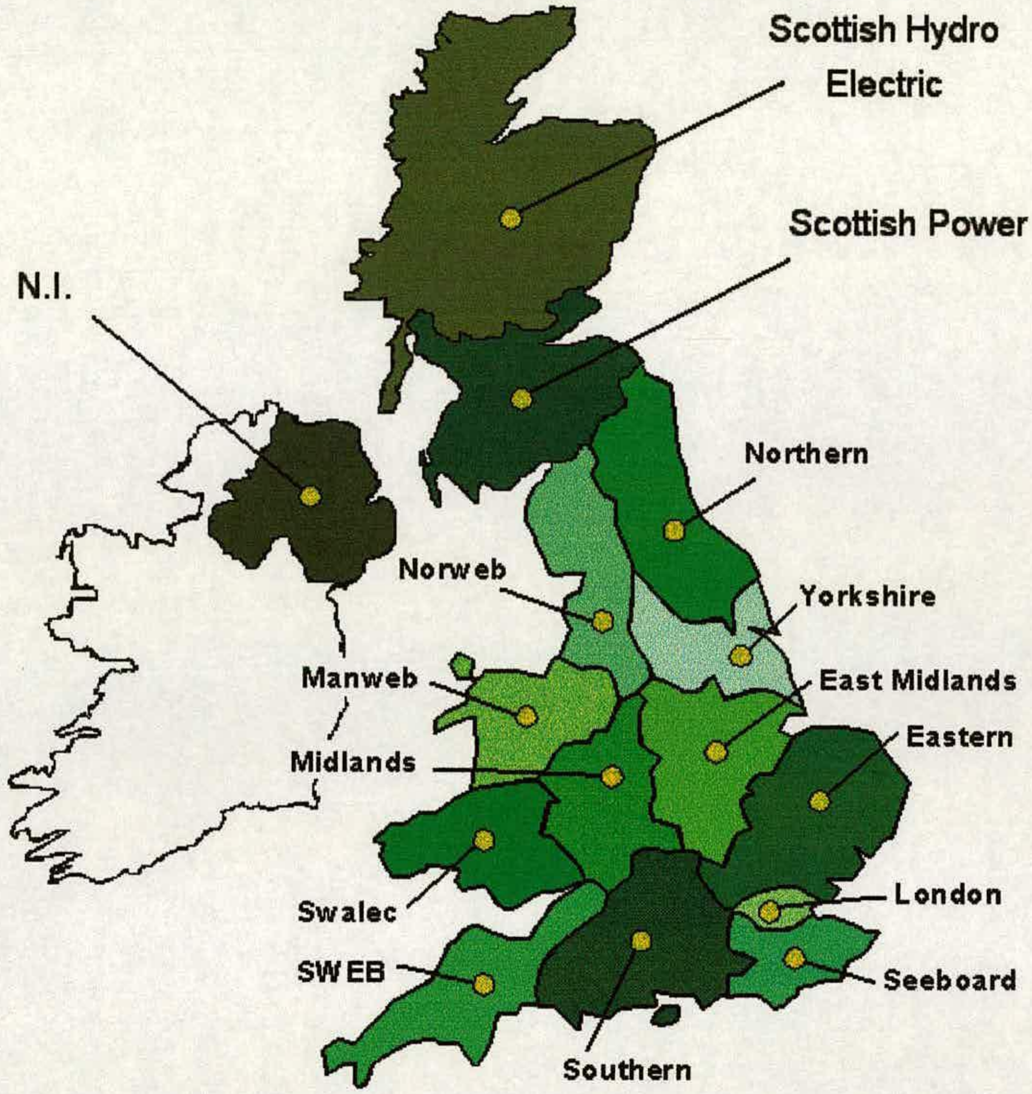


Figure 1 UK ESI, showing English & Welsh RECs, the Scottish power companies and Northern Ireland Electricity

Presently 22 million customers do not have any choice as to who supplies them with electricity, although prices are tightly regulated. These customers must purchase their electricity from the electricity Supplier within whose region their premises reside. Only 50,000 customers have the right to choose.

By early 1999, however, it is intended that the market will be liberated to allow all customers a choice of Supplier.

2.6 The ESI before Privatisation

The ESI originated in a number of small privately owned companies that were nationalised in 1947. Once nationalised, they evolved into the Central Electricity Generating Board (CEGB) serving England

& Wales and the South of Scotland Electricity Board (SSEB) and the North of Scotland Hydro-Electricity Board (NSHEB) serving Scotland.

At its peak, the CEGB supplied 94% of the total electrical energy requirements of England & Wales[2]. Electricity generated in the CEGB's region was transmitted to 12 Area Boards that subsequently distributed the energy to their customers on their local networks. However, in Scotland, the SSEB and the NSHEB both generated and distributed their electricity to their customers.

A body known as the Electricity Council was set up to provide a link with government, help develop energy policy and set prices in the ESI. There was no competitive market, and the Area Boards were restricted to selling to their local customers.

Successive Governments prohibited the ESI from purchasing foreign coal. This was quite significant in the early 1960s, as 82% of electricity was generated with coal when coal prices in the US were roughly half that of British coal[3]. The Government became aware that the electricity system was a slave to the economics of the British coal industry. However, instead of allowing coal to be bought from abroad, their preferred tactic was to increase the use of other primary fuels for electricity generation to lessen the impact of coal prices. By the 1970s, the coal-fired capacity of the CEGB had dropped to 66%, with oil accounting for 22%, nuclear 10%, gas 1.5% and hydro 0.5%. This included the eight Magnox nuclear power stations that were built by the CEGB.

One area in where economics were more properly applied seemed to be in the choice of what order generating stations were despatched in order to meet demand. The cheapest stations were despatched first, to meet base load, followed by increasingly more expensive stations until demand was met. However, the high reliance of the CEGB on one fuel source prevented this strategy from delivering its potential.

2.7 Privatisation of the Electricity Supply Industry

2.7.1 Overview

In 1988, the UK government published its plans for privatising the Electricity supply Industry in England and Wales in the White Paper *Privatising Electricity*[4].

Sale of the bulk of UK's Electricity Supply Industry happened in 1990 & 1991. The industry was floated into 17 companies. Table 1 below covers those companies that were created first:

Regional Electricity Companies	Generation	Transmission	Combined (Scotland)
Eastern Electricity East Midlands Electricity London Electricity MANWEB Midlands Electricity Northern Electricity NORWEB Southern Electric SEEBOARD South Wales Electricity South Western Electricity Yorkshire Electricity Group	National Power PowerGen	National Grid Company	Scottish Hydro-Electric Scottish Power

Table 1 Electricity Companies Created at Vesting

In England and Wales, the sale created an industry split horizontally. The Government's Area Boards, which served each of 12 regions of England and Wales, became the new industry's Regional Electricity Companies (RECs). Their main operations continued to be local electricity distribution and supply. National Power and PowerGen were created as the two main Generators of electricity. Joining Generation to Distribution and Supply became the business of the main Transmission company, called the National Grid Company. This was originally collectively owned by the RECs, but was floated in 1995.

In Scotland, the situation was different. Since the electricity network was separate from, though connected to, its English and Welsh counterpart, and significantly smaller, it was decided to create two vertically integrated companies, Scottish Hydro-Electric and Scottish Power. These were created from the North of Scotland Electricity Board and the South of Scotland Electricity Board respectively. These companies comprised Generating, transmission and supply functions.

This was followed by the sale of Nuclear Electric and Scottish Nuclear in 1996 forming British Energy. These were sold much later than the rest of the industry because a straight sale in 1990 would have created a company with very poor prospects due to the huge debts and poor assets that accompanied the operations. It was necessary to restructure the debt and sell only the portions of the Government's nuclear generation that were operating most economically. It took some time to organise this and the Government then waited until it felt the markets were ready to accept the nuclear sell-off.

During this whole period, in 1994, the National Coal Board was sold off and split into many smaller companies consisting of one or more Collieries.

Table 2 gives a summary of the events during electricity privatisation.

May 1987	Conservative Party election manifesto announces commitment to privatisation of ESI
December 1987	Select Committee on Energy starts enquiry into possible outcome of electricity supply in private sector
February 1988	Publication of White Paper, *Privatising Electricity*
March 1988	Publication of White Paper, *Privatisation of the Scottish Electricity Industry*
July 1988	Select Committee on Energy publishes its report criticising many proposals in the White Papers
November 1988	Companies to succeed the CEGB are named as National Power, PowerGen and the National Grid Company
December 1988	Second Reading of Electricity Bill in House of Commons
April 1988	Second Reading of Electricity Bill in House of Lords
July 1989	Electricity Act 1989 enacted
September 1989	Director General of Electricity Supply (DGES) appointed – Stephen Littlechild
November 1989	Withdrawal of nuclear generation from sale and creation of Nuclear Electric and Scottish Nuclear
31st March 1990	Vesting Day: Transfer of CEGB and Area Board assets to successor companies. Licenses come into effect.
December 1990	Sale of 12 Regional Electricity Companies with National Grid.
March 1991	Sale of National Power and PowerGen
June 1991	Sale of Scottish Power and Scottish Hydro-Electric
December 1995	Flotation of National Grid
July 1996	Sale of British Energy (Nuclear Electric and Scottish Nuclear)

Table 2 The Chronology of the Electricity Sell-off

2.7.2 The Introduction of Competition

One of the main aims of the new industry structure was to create a competitive market at each stage of the electricity delivery process, that is Generation, Transmission, Distribution and Supply. However, a few factors prevented perfect competition and compromises were sought. A Regulator and his Office of Electricity Regulation (OffER) was introduced to help control the development and behaviour of the newly privatised industry.

2.7.2.1 The Regulator

The Electricity Act of 1989 introduced a Regulator, also known as the Director General of Electricity Supply (DGES), to oversee the new industry. This Act set out his main responsibilities:

To ensure that reasonable demand was always met.

To ensure that holders of generation, transmission and supply licences were financially viable.

To protect customers in terms of prices and service.

To promote competition in Generation and Supply.

To promote energy efficiency.

The Act also introduced a number of licences that most parties wishing to take part would have to obtain. These licences stipulated duties that parties would have to fulfil in order to legally operate within the ESI.

These included:

- A Generator's Licence for generators who produced more than 10 MW.
- A Transmission Licence for the National Grid Company, Scottish Power, Scottish Hydro-Electric and Northern Ireland Electricity.
- Public Electricity Suppliers (PESs) Licences covering their duties as distributors and suppliers to franchise customers.
- 2nd Tier Supplier Licences required by:
  - non-PESs wishing to supply customers with demands above 100kW
  - PESs wishing to supply customers with demands above 100kW outside their region.
  - Companies buying power direct from the Pool.

The regulator cannot change the licences without the holders consent. Where there is a lack of agreement, the Monopolies and Mergers Commission can intervene. If there is still a lack of agreement, decisions are ultimately made by the Secretary of State.

Licences require holders to sign up to a number of statutory codes and agreements. All licence holders must become members of the Pool by signing the Pooling and Settlements Agreement (P & SA).

Generators and externally connected Pool members must sign the Grid code, governing the use of the transmission network and despatch procedures. Similarly, PES licence holders must comply with the distribution code, which sets down the use of distribution networks.

2.8 The Changing Structure Since Privatisation

At present, the only ESI companies left in public ownership are BNFL & Magnox Electric. In 1995, the Government's Golden Shares expired. By mid-1996, 7 RECs had been taken over, three by US utilities, two by water companies, one by a UK conglomerate, and one by a Scottish company. The US take-overs did not change the nature of the industry.

It is not clear why all these bids were made. The motives were many and varied[5]:

- Some companies might have felt that they could manage these companies more efficiently than their incumbent management.
- RECs were attractive due to their steady earnings stream associated with their regulated distribution business.
- Takeovers might have offered tax efficiencies.
- Takeover of RECs by utility companies offering other products would create a multi-utility, capable of selling tailor made packages of utility products, e.g. electricity and water, whilst improving overall efficiency by having a single customer database and billing system.

Certainly, those by the water companies would fit into the latter category. Scottish Power's purchase of MANWEB consolidated its position as a supplier of electricity and increased its strength with the prospect of the final franchise break.

Hanson created a new vertically integrated company, known as The Energy Group, with the purchases of Eastern Electricity and 6 GW of coal fired capacity formerly owned by the National Power and Powergen. Hanson then implemented its de-merger.

The benefits of creating or consolidating the vertical integration of an electricity company are not clear, since each part of the electricity pipeline is separated by tight regulation. There seems little scope for taking advantage of the combination of functions. For example, the supply function usually operates by purchasing electricity from the Pool and selling it on to customers. Generation sells electricity to the Pool. Only where there is a direct connection through fully owned distribution lines, removing the need to trade through the Pool, is there scope for efficiency savings.

It is interesting to note that nearly all the successful bids were made on RECs. The Southern Company wanted to take over National Power, but this was blocked by the DTI. The bids made by National Power and Powergen, for Southern Electric and MEB respectively, were also blocked by the DTI, who argued that those take-overs would have stifled competition and would thus be against the public interest.

Target	Bidder	Value (£ x 10^9)	Outcome
Eastern Electricity	Hanson	2.5	Completed 9/95
East Midlands	Dominion Restaurants	1.3	Completed 1/97
London Electricity	Entenergy	1.2	Completed 2/97
MANWEB	Scottish Power	1.0	Completed 10/95
MEB	Powergen	1.9	Prohibited 4/96
	Avon Energy	1.7	Completed 8/96
National Grid (Pumped Storage Business)	Mission Energy	0.7	Completed 12/95
Northern Electricity	Trafalgar House	1.2	Defeated 3/95
	Calenergy (CE Electricity)	0.8	Completed 2/97
NORWEB	Texas Energy	1.7	Defeated 10/95
	North West Water (United Utilities)	1.8	Completed 11/96
SEEBOARD	CSW	1.6	Completed 1/96
Southern Electric	National Power	2.8	Prohibited 4/96
SWALEC	Welsh Water (Hyder)	0.9	Completed 1/96
SWEB	The Southern Company	1.1	Completed 9/95
Yorkshire Electricity	AEP/Colorado	1.5	Completed 4/95

Table 3 Take-overs in the ESI Completed up to February 1997

2.9 *Competition in the UK ESI*

2.9.1 Competition in Transmission

It was deemed impractical to have a number of transmission companies that would compete with each other. This would require a number of parallel networks to have been built, the cost of which was seen to outweigh the benefits of competition in this area. The question would have also arisen as to which company would take on the present network with all the unfair advantages of not having to build a new network. Parallel networks would also have considerable environmental impact, not least visually.

Instead, it was decided to impose price controls on the company that would take over the sole operation of the national transmission network.

In order to secure the operational independence of the National Grid after its flotation, its Articles of Association and the powers of the Secretary of State, in his capacity as Special Shareholder, were altered. This was to ensure that, after a transition period, no electricity company operating in the British Market could hold more than 1% of the shares in the National Grid Group[6]

2.9.2 Competition in Generation – The Pool

A market place, known as *The Pool*, was set up for the buying and selling of electricity. The participants in the market are primarily the Generators and the Suppliers of electricity, and its function is to determine the price at which there are sufficient sellers of electricity to satisfy demand. The Pool is described in much greater detail in the next chapter.

2.9.3 Competition in Supply

At vesting, all customers with peak demands above 1 MW were allowed to seek a new Supplier of electricity from any of the licensed Suppliers within the UK. The RECs were granted exclusive rights to sell to customers within their franchise area with peak demands of up to 1MW. However, the intention was to open these local markets further. This was to be achieved in two stages, known as *franchise breaks*. The first of these occurred on the 1st April 1994 when customers with peak demands above the lower 100kW level were allowed to seek a Supplier beyond their local REC. The second franchise break, which will allow all electricity customers the right to chose their Supplier, will occur within the next two years. Originally scheduled to happen on the 1st April 1998, the break has already been rescheduled, and is to be phased in from Autumn 1998 into spring 1999. The regulator decided that the industry was ill-prepared to go ahead with competition on the original date.

2.9.4 Competition in Scotland

As discussed in a previous section, the situation in Scotland is somewhat different to that of England and Wales. The two companies own their own Generation, Distribution and Transmission Lines, and have a monopoly on supplying customers with peak demands of less than 100kW, much like the RECs.

2.9.4.1 The Scottish Interconnector

Both of the Scottish power companies are connected to the National Grid system via the Scottish Interconnector. The Interconnector presently has a capacity of 1,600MW which will increase to 2,200MW[7] once present upgrading work is complete at Interconnector site and within the North of England network.

Generation capacity in Scotland is approximately 10 GW, whereas demand rarely peaks much above 8 GW. There is thus a great potential for the export of electricity South of the border.

Table 4 provides figures for the quantity of electricity presently or forecast to be carried across the Interconnector to the National Grid.

Year	Scottish Power GWh	Scottish Hydro-Electric GWh
1994/95	26051	10794
1995/96	26893	10923
1996/97	29040	11799
1997/98	29311	11931
1998/99	30399	12066

Table 4 Electricity transmitted across Scottish Interconnector, Actuals/Forecasts[8]

Importantly, however, the interconnector's limited capacity does not affect the Scottish companies Supply businesses in England and Wales. Since both the Scottish companies purchase from the Pool they can sell much more electricity than the interconnector could carry South of the border. Indeed, it should not affect PESs South of the border selling to Scottish customers either, so long as they can compete on price. The Pool system allows Suppliers to ignore the technical characteristics of the system. The Grid Operator co-ordinates with the Scottish companies to ensure that the actual electricity flows are kept within limits of the interconnector.

The technical limitations of the interconnector do affect the Generators' businesses, however, since the capacity of the interconnector determines whether they can trade electricity across it. Up to April 1997, the amount of electricity that could be traded across the interconnector, to and from the Pool, was restricted, so that the sum of the trades, irrespective of their direction, never exceeded the interconnector's capacity. Of course, this does not reflect the technical reality of electrical systems, where limits are usually governed by net flow. OffER then changed the rules governing the use of both the Scottish and French interconnectors. Since April 1997, net flow was taken into account and the rules changed so that trades were only restricted so that the aggregate across the connector was kept within its technical limit

2.9.4.2 Transmission and Distribution in Scotland

The DGES has imposed pricing restrictions on the use of the transmission and distribution networks of both Scottish electricity companies. This is to encourage fairer competition with other electricity companies that might want to compete with them for Scottish customers, and who will therefore have to pay one or more of the Scottish companies for the use of their lines.

In formulating these price restrictions, the DGES noted that Scottish Hydro-Electric was in a special situation:

1. A major fraction of Scottish Hydro-Electric's generation mix was, not surprisingly, hydro-electric. All of the large schemes were well established and this, combined with the superior cost efficiency of this form of generation, means that they could create electricity particularly cheaply. Because there were few if any opportunities for other electricity companies to acquire existing or build new hydro-electric schemes, this counts as a significant competitive advantage for Scottish Hydro-Electric, one which might hinder fair competition.

2. In Scottish Hydro-Electric's region, the terrain over which the distribution and transmission lines traverse was particularly extreme. This made the building and maintenance of these lines much more costly than in most of the UK. This has been identified as a competitive disadvantage.

In taking into account these unique circumstances, the DGES decided to impose a levy, known as the *Hydro Benefit*, which required Scottish Hydro-Electric to pass on a portion of its profits from generation to subsidise its transmission and distribution businesses. This was intended to:

- Remove some advantage from its cheap hydro generation

- Remove some disadvantage from its high cost transmission and distribution operations

- Avoid the position where Scottish Hydro-Electric might argue that it needed to charge other electricity companies higher rates for use of its lines, whilst cross subsidising its own higher transmission/distribution costs with its higher generation profits.

2.9.5 Price Regulation

In order to protect customers within the temporary monopoly franchises and 2nd-Tier Suppliers paying to use monopoly transmission and distribution systems to deliver electricity to their customers there has had to be a level of price regulation. At the same time, it is necessary to ensure a fair income for the regulated business. This generally takes the form of capping the price for the use of capacity of these networks, or of the price of electricity which the monopoly franchise holder can charge.

The most popular concept in the regulation of prices in the UK ESI has been the so-called *RPI-X* price control formulae. These are used to lower the caps from year to year, providing an increasingly better deal for the customer of the service, and an incentive for the supplier of that service to lower its costs in order to at least maintain the same level of profits. *RPI*, or Retail Price Index, is thought to represent closely inflation, and is included in the price-cap formulae to ensure that this is taken into account and real prices are changed. The *X* factor determines the percentage drop in the cap, in real terms. In the most simple cases, the following year's cap is calculated by first evaluating RPI - X. If this value is positive, then the cap is increased by this percentage. However, if it is negative, then the cap is decreased by this percentage. The price control formulae, though, are rarely as simple as this.

To complicate matters, OffER has made a number of one-off cuts in the various caps at various stages over the last few years, after it has published reviews of specific parts of the industry. For example, after its second review of distribution prices, it made one-off cuts to the distribution price caps for each REC of between 10 and 13%. This was intended to rebalance what it felt as overgenerous terms for the years previous, and at the same time altered all of the X factors to make the price formulae for distribution stricter. The Scottish businesses have not had any one-off cuts made in prices, although their X factors have been changed.

	Vesting Control X factor 1990/91 – 1994/95	One-off reduction in 1995/96	One-off reduction in 1996/97	X factors for revised second control: 1997/98 - 1999/2000	Cumulative reduction in allowable unit revenue: 1999/2000 against 1990/91
Eastern	+0.25	-11	-10	-3	-26
East Midlands	+1.25	-11	-13	-3	-26
London	0	-14	-11	-3	-30
ManWeb	+2.5	-17	-11	-3	-26
Midlands	+1.15	-14	-11	-3	-27
Northern	+1.55	-17	-14	-3	-30
Norweb	+1.40	-14	-11	-3	-26
Seeboard	+0.75	-14	-13	-3	-30
Southern	+0.65	-11	-10	-3	-25
Swalec	+2.5	-17	-11	-3	-26
South Western	+2.25	-14	-11	-3	-24
Yorkshire	+1.3	-14	-13	-3	-28
Average	+1.1	-14	-11.5	-3	-27

Table 5 X factors and allowable revenue reductions for RECs distribution businesses

	Vesting control X factor: 1990/91 – 1994/95	OffER's initial revised X factor 1995/96 - 1999/2000	MMC's revised X factor for HE: 1996/97 - 1999/2000	Cumulative reduction allowable unit revenue: 1999/2000 as against 1990/91
Scottish Hydro-Electric	-0.3	-1	-2	-10
Scottish Power	-0.5	-2	n/a	-11

Table 6 X factors for the Scottish Distribution businesses.

2.9.6 Transmission Price Control

The GO, currently NGC, charges both Generators and Large Customers (e.g. RECs) for both connection to the grid and use-of-system. The connection charges are meant to recover the costs of building, operating and maintaining connection assets, e.g. sub-stations, spur lines, etc. The use-of-system charges, on the other hand, are intended to recover the costs of building, operating and maintaining the core network.

Although it is straightforward to cost the assets needed connect a new user or generator to the network, it is more difficult to estimate the cost of reinforcing the network elsewhere, downstream and deeper within the network, to take account of the new strain on the system. However, to include these costs in the connection charges is seen by both OffER and NGC to act as a disincentive to new entrants. Since this would harm the potential for more competition, the connection charges just cover the essential assets to connect the user to the system. The rest of the costs are recovered in use-of-system charges in such a way that all users of the system cross-subsidise network reinforcement.

The use-of-system charges are calculated slightly differently for electricity consumers and Generators. However, all use-of-system charges are calculated using a tariff system, which provides weighting for each of up to 16 geographical zones, one set for demand-side consumers, and another for Generators. The rational for this is sensible. Generators located further away from concentrations of electricity users are clearly more of a burden on the system than Generators located closer to them. Similarly, electricity users situated closer to concentrations of Generators are less of a burden, than those situated far away. Indeed some users receive a negative charge. Some Generators in the south-west are presently paid for using the system. This provides the incentive for Generators to build new generating stations in more efficient locations with regard to transmission costs.

Electricity consumers are also charged according to the *Triad* system. At the end of winter, NGC nominates 3 half-hour periods according to a set of rules. NGC then charges consumers based on their maximum demand in each of these three periods. NGC gives no warning of which periods will be chosen. This provides an incentive for customers to try to avoid charges by decreasing its demand during periods it suspects might become a triad period. Since customers' predictions vary considerably, this helps to dampen out peaks in the system and therefore make it more efficient.

Charges paid by Generators are calculated differently, however. Although they also pay according to a similar geographical tariff scheme, Generators pay according to their generating units' registered capacity.

NGC's licence requires the company to use its best endeavours to ensure that in any year, its average charge for services covered by the price control does not exceed a maximum. Since it charges for use of its system on the basis of maximum demand, then these values are measured in £/kW.

Chapter 3 The Pool

3.1 Introduction

The Pool is a trading mechanism for the Electricity Supply Industry, linking the sellers of electricity, the Generators, to large customers and Suppliers. The Pool is like a commodity spot market for electricity, but differs in a number of crucial ways:

- The Pool is compulsory – Virtually all electricity trading occurs through the Pool as all the substantial Generators (> 50 MW) are compelled to do so under their licence agreements
- Buyers and sellers do not deal directly with each other, striking mutually agreed prices. Instead, sellers make offers to generate and get paid according to a complex algorithm. Buyers, on the other hand, do not make any offers. The Grid Operator (GO), presently the National Grid Company plc (NGC), makes quantity bids on their behalf. There are no demand price bids.
- All trades relate to day-ahead business, with no facilities for trade on the day or beyond the day ahead.
- Sellers make uncommitted offers. They incur no penalties for not generating, and it is the purchasers who pay for the replacement of this lost power.
- Electricity, in the large amounts traded, cannot be stored, so the Pool attempts to match demand and supply. The GO is largely responsible for this.

Thus, the Pool performs three functions:

1. Scheduling and despatch of generating units to meet demand. It attempts to match offers to generate with forecast demand.
2. A price for electricity is set, taking into account the issues of marginal cost, supply and demand that would affect its worth.
3. Centralised Settlement, handling the resulting commercial transactions.

3.2 The Trading Process

The trading process begins a day ahead of the actual day on which the traded electricity is to be transferred.

This process follows a number of steps:

1. Bid Submission

2. Demand Forecast

3. The Unconstrained Schedule

4. Operational Schedule

5. Data Collection

6. Settlement

3.2.1 Bid Submission

Each Generator submits a bid for each of his generating stations for despatch the following day. These bids comprise many pieces of information. They include:

- A start-up price (£) – The cost of starting up the generating station.
- A No-load cost. The fixed price of running the generating station (£/h).
- 3 incremental £/MWh prices, each of which must be more than the former.
- Two capacity figures giving the elbow points at which the price shifts between these incremental prices.
- A Maxgen price (£/MWh) – The price of generation for running the generating station above its normal operating level. This takes account of the extra stress on the plant when running it near capacity.
- Availability bids. The amount of electricity that the generating station can supply for each half-hour of the following day. This allows Generators control over the amount of output and its marginal price over the whole day.
- Generating station technical characteristics. These include the speed at which the generating station can increase or decrease capacity, known as the ramp rate, the synchronising of generation where account is taken of the level of output at which the generating station is able to synchronise with the grid, and the minimum stable generation.
- Finally, the Generator can submit constraints on the use of the generating station via inflexibility declarations. At their most restrictive, this might stipulate that the generating station can only produce a fixed amount of electricity for a fixed period of time. A less restrictive constraint might be the declaration of how many times the generating station can be shut down between daily peaks. These declarations give the Generators some say in how their generating stations are used.

Generators are allowed to bid any values, and these don't have to reflect true technical values or real costs, just so long as they can meet the demand that is finally requested. The Pool does not have the resources to check carefully every bid, and has little power to impose sanctions if a Generator is found wanting. However, the Pool can refer the Generator to the Office of Electricity Regulation (OffER).

The bids are processed by the GO.

3.2.2 The Demand Forecast

Before beginning scheduling, a demand forecast is created by the GO. This forecast uses information such as:

- Historical demand
- Weather forecasts, especially temperature forecasts
- TV schedules
- Estimates of demand from large customers (> 250 MWh in a half hour period)
- Estimates of electricity flow through the interconnectors
- NGC pumped storage demand

3.2.3 The Unconstrained Schedule

This schedule is created with information from the price bids and the generating station dynamic characteristics. It does not take account of other technical constraints such as transmission line behaviour.

For each half-hour of the day ahead, the GO needs to compile a list of generating stations that must be scheduled to meet the forecast demand. Each list is created by stacking the generating stations in price order, cheapest first, adding up their output until forecast demand is reached. This then completes the list. The lists are adapted to take into account the dynamic characteristics of the generating stations. Slow generating stations are also scheduled at times of low demand so that they are ready to be run up for times of high demand.

The prices for each generating station are calculated using their bids. For most of the day, this includes the incremental cost, start-up cost and accumulated no-load price, although there are exceptions (see 3.2.3.1). The latter two are spread over any continuous periods in which the generating station is chosen to schedule.

For each half-hour, the price of the most expensive generating station chosen to run becomes the *System Marginal Price* (SMP). Only generating stations bid as flexible can set SMP, though. In theory, SMP should reflect the marginal energy cost, or, in economic terms, the opportunity cost of supply. This important figure is used to calculate two other important prices, the *Pool Selling Price* (PSP), the price purchasers of electricity from the Pool pay, and *the Pool Purchase Price* (PPP), the price paid to the Generators for their output.

Presently, the GO uses a computer programme called *Generation, Ordering And Loading* (GOAL). This relatively old system, once used by the CEGB, is still employed to schedule the generating stations. It used to use the CEGB estimates of marginal costs for each of the generating stations on the grid, but now uses the price bids to calculate scheduling.

3.2.3.1 Table A and B periods

Most periods of the day are classed as Table A periods, where whole generating stations are either started up, maintained at a fixed output, or shut down. However, during periods of quite low demand, it may be more efficient to lower the output of some of the generating stations, instead of switching out whole stations. These periods are known as Table B periods, and their number is capped at 10 per 24 hour period. During these half-hours, the prices are calculated in a different way. Instead of counting start-up cost, accumulated no-load price, and incremental cost, the price in Table B periods just uses the incremental costs. This is thought to provide more realistic prices for when capacity far outstrips demand. The resulting low Pool price is considered to offer the incentive for users to increase demand, and therefore should encourage less volatility in demand.

3.2.4 The Operational Schedule

The Operational Schedule is a revision to the Unconstrained Schedule, taking into account the technical constraints of the transmission network. The resulting instructions from this schedule are sent out to the Generators on the afternoon before the day on which they apply. Some generating stations in the Unconstrained Schedule will be omitted from the Operational Schedule, whilst others, who were not included in the Unconstrained Schedule, will be added. This is all due to the necessity of providing a secure, stable network, maintaining the correct line voltages, meeting the losses which occur across the lines, and ensuring that the power carrying capacity of different parts of the network is not exceeded.

3.2.5 Data Collection

This part of the process determines the actual amounts of electricity that have been either created by the Generators, or consumed by the large customers and Suppliers.

During settlement, each of the Generators is paid according to the volume of electricity that they have delivered to the network. The GO has access to meters that measure the output from each of the generating stations.

In addition, the GO determines the actual consumption of electricity. There are meters at each of the 300 Grid Supply Points. This data, in addition to all the meter data from 2nd Tier Customers is used to calculate the consumption of each party connected to the network.

3.2.6 Settlement

The Settlement phase of trading is that in which all parties are paid monies that they are due, or charged for monies owed.

3.2.6.1 The Pool Purchase Price (PPP)

As previously mentioned, the Pool Purchase Price is based on SMP. The formula for its calculation uses two other quantities.

3.2.6.1.1 Loss Of Load Probability (LOLP)

LOLP is the probability that the system will have insufficient generation capacity to meet expected demand in any half-hour. The value of LOLP is calculated using a programme that compares forecast demand with expected available capacity. This value is adjusted to reflect decreased load and increased output if LOLP pushes prices up (is high). LOLP is positively correlated to the capacity margin, the percentage of unused available capacity, but extremely non-linear. LOLP generally becomes significant only when the capacity margin falls below 15%, and increases rapidly when this margin falls below 10%.

3.2.6.1.2 Value Of Lost Load (VOLL)

VOLL is marginal cost of lost supply or the value to the marginal consumer of the last kWh supplied. At vesting, VOLL was set by the DTI at £2000/MWh, and since raised by RPI. One possible way to have calculated VOLL would have been to survey consumers. However, this method was rejected as it was thought that it would provide too disparate results, with values quoted being very subjective and highly dependent on which consumers were asked, what time the loss occurred, for how long, and to what extent – partial or total loss of supply.

The alternative was to estimate the annual marginal cost of capacity required to meet demand at the required reliability standard. In an optimal system, this would be equal to VOLL. This method was chosen by the DTI.

The marginal cost of capacity was assumed to be that of an open cycle gas turbine Generator, i.e. £40 per kW per year. The CEGB security standard is to limit brown outs to 20 hours per year. Dividing one by the other gives the value of VOLL, or £2/kWh (£2000/MWh).

3.2.6.2 The PPP Formula

PPP is calculated as follows:

PPP = (1 – LOLP) SMP + LOLP x VOLL

The first half of the sum is the energy term, the latter is the capacity element. The capacity term is included to provide an incentive for Generators to maintain an available reserve.

3.2.6.3 Payments to Generators

The payments to Generators use the value of PPP. The Generator payments depend on whether or not their generating stations were included in the Unconstrained Schedule or not, and whether or not their generating stations were asked to generate on the day. The Operational Schedule would have defined most of the latter, but some of the generating stations would have had instructions changed during the day to meet errors in forecasting.

3.3 Trends in Pool prices

The behaviour of Pool price has shown some significant trends[9] including:

- Prices increase significantly as the capacity margin gets smaller. This is due to both the way in which Pool prices are calculated to take into account the likelihood of demand exceeding supply and Generator bids increasing. Generators can increase their bids in line with the increasing likelihood that their generating units will be scheduled by the GO due to the diminishing capacity margin.

- Interestingly, capacity availability tends to move with demand across the year, as Generators declare their sets unavailable during seasons of low demand, particularly summer.

- Demand is flatter in summer than in winter.

- Peaks in demand usually occur at lunchtime, early and late evening. These peaks co-incide with meal preparation and the lighting up of internal and street lighting. In winter, the late peaks become closer until they eventually join since the typical evening mealtime then co-incides with dusk.

- Domestic customers on *Economy Seven* (*E7*) show a small peak in demand during the night. Electricity Suppliers have tried to lower costs by using different *E7* phases.

- Winter off-peak demand is comparable to Summer off-peak demand

3.4 Membership

The Electricity Pool is set up as a trading association. All members sign the Pooling & Settlement Agreement (P&SA) which defines the rules governing the trading arrangements. In addition to members, there are *associates* that have no vote, but can observe meetings.

These associates include:

- Aspiring Generators
- Meter operators
- OffER
- Four agents responsible for Pool functions

The latter include:

- The Settlements Systems Administrator (SSA) who operates the settlement system and supports its development.
- The Pool funds administrator (EPA) who ensures Pool funds are transferred between Pool members.
- The GO who provides the interface to the physical system operations.
- The Ancillary Services Provider (ASP) who contracts for ancillary services to enable voltage and frequency control standards to be met.

At present all these posts are filled with representatives from NGC or its subsidiaries.

3.4.1 The Pool Executive Committee

Overall supervision of the settlement system and its operation is the responsibility of the Pool Executive Committee (PEC) composed of individuals elected by the two classes of Pool members, Generators and Suppliers. The committee's functions include:

- Monitoring Pool functions
- Developing new trading mechanisms
- Problem Solving

The committee consists of five Generators and five Supplier representatives.

Generator representatives are elected by a system which allocates seats in relation to the amount each one trades in the Pool. Of the five seats, three are currently held by NP, PG, NIE. One is held by a representative of the Small Independent Generators, and the remaining one by a representative of the remaining Generators, GROG, or Group of Other Generators.

On the supply side, the RECs appoint four representatives. The remaining seat is occupied by a representative of the independent Suppliers. OffER and Pool agents are entitled to attend PEC meetings but have no vote. A Chairman is elected for one year, from the Generators and Suppliers alternately. The committee meets monthly.

Despite the influence of the PEC on Pool proceedings, overall responsibility and authority is retained by the Pool members who are required to sanction PEC decisions on key issues at the quarterly meetings. Members also vote on matters when there is dissent amongst the PEC.

3.4.2 The Chief Executive Office

Routine monitoring of the key functions and administration of the Pool is the brief of the Pool's Chief Executive Office. This Office takes forward work on developing future trading arrangements, including software development. It reports to members via the Pool Chairman. The CEO organises co-ordination of the Pool subcommittees and working groups established by the PEC and members. The CEO also co-ordinates the SSA, EPA, GO, and ASP.

3.4.3 Decision Making

Decisions are made in the PEC by a show of hands. If there is a dissenter, then the decision is appealed to members. This is then often carried out by a postal, weighted vote. The weighting is calculated in relation to the volume of business, but there is a cap and minimum of one vote. Any weighted vote can be contested as long as the dissident Pool member can find a seconder. The vote at the subsequent meeting is simply a show of hands, followed immediately by a weighted vote if need be. However, even this vote can be contested by referral to OffER. However, OffER is empowered only to recommend, although to date the Pool has always complied. OffER could refer the matter to the MMC, and if necessary, to the Secretary of State.

3.4.4 Difficulties

3.4.4.1 Decision Making

Perhaps not surprisingly, with this amount of bureaucracy, the Pool decision making process is prone to stalemate, especially since the Generator/Supplier distinction has blurred and interests diversified. Most significant changes to date have been decided by the regulator.

3.4.4.2 Lack of Company Status

The Pool is not a company. Therefore, contracting and outsourcing is complicated by the lack of legal responsibility of the members. Hence, the members are considering establishing a 'Poolco' to exist simply as a body to pay staff, rent premises and purchase services on behalf of the Pool.

3.4.4.3 Barriers to Active Membership

Pool membership is restricted to Generators and Suppliers. However, some large consumers are now members as 2nd Tier Suppliers since they can purchase electricity directly from the Pool.

Barriers to membership are unlikely to be financial, since membership costs only £250 pounds per year. However, Pool members are concerned that there is too much documentation to absorb before being able to take an active role in the running of the Pool.

3.4.5 Costs of The Pool

The costs of the Pool are met by charging members according to the amount of business they carry out in the Pool. The Pool has an auditing contract with an outside accounting firm who monitors the Pool and provides independent reports.

3.5 Pool Reform

3.5.1 Criticisms of the Pool

During its years of operation, there have been many criticisms of the Pool. These include:

- Calculations of Pool prices (System Marginal Price and capacity payments) are complex.

- Capacity payments do not respond to short-term changes in capacity margin, are a poor signal for the long term, and are not working as intended.

- Bids into the Pool are not reflective of costs. Movements in Pool prices have not matched reductions in costs. Generators and Suppliers are not faced with the full costs and risks of their actions.

- Market power has been a factor in maintaining or increasing Pool prices. Present trading arrangements have facilitated the exercise of market power at the expense of customers by enabling all Generators to receive a uniform price which in practice has been set by just a few of them; this market power has involved a lack of competition to run coal-fired (and oil-fired) plant.

- Liquidity in the contracts markets has not developed to the extent it has in other energy markets, in part because of the complexity of the Pool. Increasing interactions between the gas and electricity markets will lead to inefficiencies if Generators are not faced with the financial consequences of withdrawing scheduled output from the Pool.

3.5.2 Pool Reform Proposals

OffER has recently published[10] the results of an open review into Pool Reform that was begun in October 1997. In this review, a number of proposals are put forward. The proposals are to put in place trading arrangements more like those adopted or being adopted in other commodity markets and competitive energy markets. According to OffER, they would be more efficient and would provide greater choice to market participants while maintaining the operation of a secure and reliable electricity system. Amongst the proposals are:

- Forwards and futures markets would be organised by independent market operators as required by market participants. They could operate up to several years ahead and would evolve in response to demand.

- A voluntary short-term bilateral market would operate from at least 24 hours before the start of a trading period to about 4 hours before it. It would provide market participants with the opportunity to "fine-tune" their positions by trading a range of standardised products.

- When the short-term bilateral market closes, a voluntary balancing market would open to enable NGC as System Operator to balance generation and demand, taking into account and resolving any constraints on the transmission network. It would accept bids to buy and sell electricity on terms reflecting conditions closer to real time than in the present Pool. It would also call upon ancillary service contracts for frequency response and reserve to assist in balancing the system in real time.

- There would be a settlement process for imbalances. Imbalance prices would apply to any differences between market participants' contract positions (including trades in the balancing market) and the metered volumes of output that they actually supply or are deemed to have taken. These imbalance prices would be based on the average costs to the System Operator of the trades it needed to carry out in the balancing market, excluding costs that related to relieving constraints. They would provide stronger incentives than at present for Generators and Suppliers to meet their commitments.

- Initially, the basis of transmission charging and recovering transmission constraint costs would remain as at present. Industry expertise should be involved in implementation, experience should be monitored, and the issue reconsidered in the next transmission price control review, with a view to implementing arrangements more reflective of costs and market conditions if that seemed appropriate.

Chapter 4 Electricity Supply Price Risk: A Review

4.1 Introduction

In late 1998, greater competition is to be phased into the UK electricity supply market[11,12] in the second of what *Office of Electricity Regulation* (*OffER*)[13] has termed the *Franchise Breaks.*

Electricity Suppliers are exposed to significant risks associated with the prices in the Pool, the UK market for electricity. Electricity supply is a large turnover, low profit-margin business[14], and coping successfully with these risks is extremely important to maintain these slim margins.

This is also an important issue for the consumer. Presently, the way that Suppliers deal with these risks goes some way towards determining the price that customers pay for our electricity: this will almost certainly take on even more significance once the final Franchise Break has taken place.

4.1.1 The Pricing of Electricity

To inject competition into the electricity market for England & Wales, it was decided to create a day-ahead futures market for electricity, known as the Pool.

As discussed in the last Chapter, the Pool performs three functions:

1. Scheduling and despatch of generating units to meet demand. It attempts to match offers to generate with forecast demand.

2. A price for electricity is set, taking into account the issues of marginal cost, supply and demand that would affect its worth.

3. Centralised Settlement, handling the resulting commercial transactions.

The price in the Pool is determined by a bidding process, described by the Pool Rules[15]. These rules are designed to create a market price for electricity for each half-hour of every day.

All Generators are compelled by their licence agreements to trade all electricity from generating units with outputs of over 50 MW through the Pool. Hence, Suppliers and customers are compelled to purchase most of their electricity either straight from the Pool or via one or more third parties at prices either directly, or indirectly related to the Pool price.

The flow of payments is shown in Figure 2.

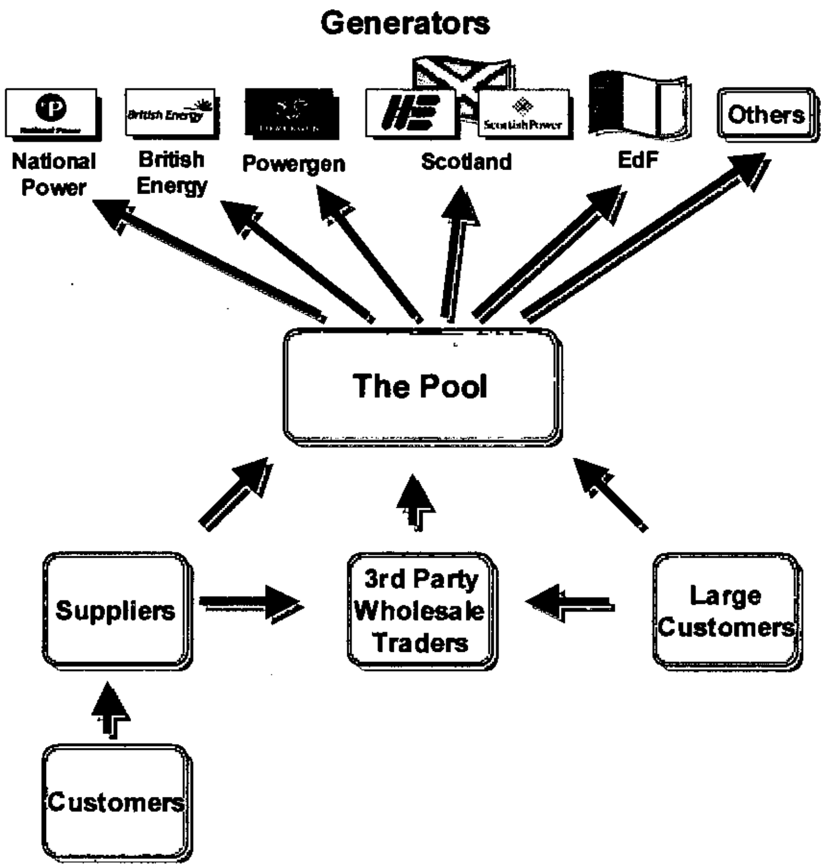


Figure 2 Flow of Payments via the Pool

4.1.2 Electricity Supply Contracts

4.1.2.1 The Electricity Bill

The electricity bill presently arrives in many different forms depending on the type of customer to whom it is being sent:

- *Domestic Customers* usually receive a bill that does not reveal much about the component costs of electricity supply. There are usually no more than two tariffs and a fixed charge. The two tariffs stipulate a day and a night price for electricity, as popular with the well-known *Economy 7* (E7) pricing scheme. The fixed charge reflects the high cost of infrastructure to supply electricity. The Franchise Break might lead Suppliers to offer customers a greater diversity of billing options.

- *Larger* Customers, with peak demands of less than 100 kW, receive a maximum demand charge (averaged over half an hour), a fixed charge, and a unit charge. The maximum demand charge varies by season. The fixed charge includes a supply capacity charge usually set higher than maximum demand.

- *Commercial/Industrial Customers* with peak demands of more than 100kW receive a bill that includes an optional maximum demand charge, a fixed charge, and a variable unit charge. The unit charge depends on when the electricity is used. This is known as a Seasonal Time of Day (SToD) tariff and reflects more closely the cost of electricity at different times of day and days of the year. This tariff scheme usually gives a different price for night & day, summer & winter, and weekend & weekday.

- *Some 2,000 customers* have Pool related contracts. The unit cost is linked to actual Pool prices that occur at each half-hour of each day of the contract. In addition to these unit charges, the customer will pay fixed charges including a capacity charge and an administration charge. These customers often have particularly large electricity demands and typically have an on-site ability to manage load.

Usually, the larger the customer, the more transparent are his electricity charges. Table 7 provides examples of different types of customers, their electricity costs, and where this money goes.

Customer Type	Domestic	Supermarket	Small Factory / Hospital
Annual Bill	£ 405	£ 42,000	£ 475,000
Maximum Demand	< 100 kW	100 kW – 1MW	> 1 MW
% Cost Transmission	5	5	5
% Cost Distribution	26	22	15
% Cost Supply	7	4	1
% Cost Levy	10	10	10
% Cost Generation	52	59	69

Table 7 Example breakdown of costs for various customers. Source: OffER

If customer's Supplier does not own the local distribution network, he is charged for the use of:

- The local distribution system

- The National Grid

The Supplier usually passes on these charges to the customer with a transparent pricing system.

The local distributors' charges vary by company, but in general they charge for the use of their resources in up to five ways. There is often a:

- One–off connection fee

- Fixed monthly standing charge

- Availability charge, the maximum expected capacity that might be needed by a customer, multiplied by a given rate, agreed at the beginning of a contract

- Maximum demand charge, often determined by a customer's maximum demand within a given period, e.g. during winter, multiplied by a given rate

- Unit charge, sometimes differentiated by time

The use of the transmission network is charged according to the *Triad* system. At the end of winter the NGC, as the Grid Operator (GO), nominates 3 half-hour periods. The first of these must be the half-hour in which there was the maximum system demand during the year. The second period must be the half-hour in which there was the next highest system demand at least 10 days from the first period. The third period, following the same trend, must be the half-hour in which there was the next highest system demand at least 10 days from either the first or second periods. The GO then charges consumers on the basis of their average demand during these three periods. The actual charge is calculated by multiplying this average demand figure by a rate depending on the geographical location of the customer's site, see Table 8. This system is intended to penalise those within an area where there is a large amount of demand and a little generation plant, and reward those that are within an area where there is a large amount of generation and little demand. This is justified on the basis of the costs of transferring power between regions to meet demand.

Zone by REC	Zone Number	Demand Infrastructure Tariff(£/kW)
Northern	1	0.535219
Norweb	2	5.316077
Yorkshire	3	4.830925
Manweb	4	5.357149
East Midlands	5	7.629085
Midlands	6	8.233965
Eastern	7	9.332248
Swalec	8	14.606236
Seeboard	9	10.505439
London	10	14.061193
Southern	11	13.063725
South Western	12	16.389404

Table 8 Use-of-system Zonal Tariffs, Source: NGC 1998

The GO gives no prior warning of which periods will be chosen. This provides an incentive for customers to try to avoid charges by decreasing their demand during periods it suspects might become a triad period. Since customers' predictions vary considerably, this has the effect of dampening out peaks in the system and therefore makes it more efficient.

4.1.3 The Customer's Perspective

An electricity customer rarely buys electricity from a Supplier on a day-to-day basis. The customer will often request a fixed-price contract for at least six months or a year. The contract might stipulate a single tariff for a unit of electricity consumption, e.g. £15 per MWh, or it might stipulate SToD tariffs to reflect, for example, the higher cost of electricity during peak periods and the lower cost at times of low demand. Tariffs are normally calculated to recoup the expected cost of electricity which the customer is forecast to consume.

These long-term contracts are often attractive to the customer as they reduce his exposure to the fluctuations in the price of electricity in the Pool. This allows him to budget more closely for his outlay for electricity during the period of the contract, helping him to predict cash flows. In the case of a commercial customer, this, in turn, helps him to invest more confidently in business projects. A customer's level of preference for this kind of contract often depends on how much of his annual budget accounts for electricity costs. A company whose electricity costs represent less than 1% of its annual costs is probably going to be less concerned about its exposure to the fluctuating electricity price than a company whose electricity costs represent, say, 10% of its budget. For example, *The Body Shop International plc*'s electricity costs represent just 0.3% of sales, but nevertheless they manage their energy consumption carefully[16].

Competition for business ensures that Suppliers are prepared to accept fixed-price contracts.

4.1.4 The Supplier's Perspective

When considering renewing a contract or establishing a new contract with a prospective customer, questions the Supplier needs to answer include:

- Does he want the business from this customer?
- If so, what price should be sought?

In order to answer these questions, the Supplier also needs to consider his strategic goals[17]. For example, the company may have decided to take on less profitable or more risky contracts in order to meet a market share goal. Inevitably, they will also want to assess:

- What level of risk the contract might represent.
- Whether they would be prepared to take on this risk.
- How would they deal with the risk exposure with respect to that contract.

The next section discusses the issue of risk and its measurement.

4.1.5 Risk – Its Definition and Measurement

The Concise Oxford Dictionary[18] includes amongst its definitions of 'risk':

'*n.* hazard, chance of or *of* bad consequences, loss, etc.'

A more suitable definition of risk related to business operations is:

'the uncertainty in the outcome of the Profit & Loss Statement'[19]

Consider a business project. It may take the form of, for example, an investment in a stock or the drawing up of a contract with a customer. Whatever its actual form, the business manager pursues such a project with the hope of achieving some return on the investment of his resources. Often, it is a financial return that the manager is hoping to achieve. In this context, risk can be considered as a measure of the likely deviation from what he expects will be the project's financial performance. Few business projects are risk free.

There are usually three possible outcomes from a risky business project:

- It makes roughly as much money as was expected
- It makes significantly less money than expected
- It makes significantly more money than expected.

The first outcome is usually the most desirable. The latter two are usually undesirable.

Making less money than expected is undesirable and may lead to a loss if the revenue gained from the project is less than its costs. In the worst case, this may lead to the failure of the business if it cannot withstand the loss.

Often, making more money than expected is also undesirable, though perhaps less serious. Unexpected revenue is often used much less efficiently than properly predicted revenue. Formulating long-term strategies and plans are key business activities. The efficacy of these activities goes someway towards determining a business's competitiveness. Business managers can incorporate only predicted revenues into their long-term strategy and financial plans. For example, they can usefully earmark future revenue to fund new projects, or improve the terms of debt finance with lenders. Unexpected revenue can form no part of efficient planning. It may represent missed opportunity.

4.1.5.1 Risk Measurement Techniques

Risk measurement techniques aim to provide an indication of the probabilities of different levels of deviation from the expected, most likely outcome of a project. Most are based on the analysis of historical performance data to provide information about likely future deviations.

A higher risk value of Project A over Project B could suggest that either Project A has a higher chance of the equivalent level of deviation than Project B, and/or an equivalent chance of a higher deviation.

Just measuring the likelihood of different degrees of deviation is not enough, however. Generally, in planning projects, managers will also consider their expected return or perceived value. Managers may be happy to pursue projects with significant probabilities of large degrees of variation if their expected return is high enough, and generally will not pursue projects with low expected returns unless they are seen to have a very slight chance of significant deviation.

In financial markets, for example, *variance* is a popular measure[20]. Variance provides a standard and well-understood indication of the amount of spread of a data set about its mean. Thus, if a stock that has demonstrated, historically, higher variance in its returns than other stock, it could be considered to be more risky if its expected return is not high enough. Therefore, an investor may wish to avoid such stock and invest in some less risky.

Variance has limited use as a measure of risk since it does not take into account expected outcome. There exist more sophisticated techniques that attempt to provide an improved measure of risk, such as that created by Pollatsek and Tversky[21]. Their measure incorporates both variance and the value of the expected outcome, so that it can more readily be used to compare directly and to rank the desirability of different projects.

Often risk measurement techniques are designed for specific applications.

4.1.5.2 Risk-Value Models

Managers, with finite resources, often have to choose between a number of different projects with different levels of risks. *Risk-value models*[22] aim to provide a means of ranking the desirability of different projects, taking into account their expected returns, a probability distribution of deviation and the perceived effect of different levels of deviation, described as a utility function.

4.2 Risks in Selling Electricity in Fixed-price Contracts

What creates the risk in an electricity contract?

The two fluctuating variables provide the source of the risk in an electricity supply contract:

- The price of electricity in the Pool
- The amount of electricity demanded by the customer

As mentioned in section 4.1.3, customers tend to like fixed-price contracts as it makes their outlay for electricity more predictable. Fixed-price electricity contracts, then, provide customers with a reduction in risk. The customer need only be concerned with matching his planned levels of demand since they are guaranteed fixed electricity prices. They need not be concerned with the fluctuating electricity price in the Pool. Whilst they might find such a reduction in risk attractive, it usually means an increased risk for the Supplier.

In providing the customer with a fixed tariff, or set of tariffs, the Supplier has made some estimate of the fluctuations of the electricity price and of the customer's demand that will occur during the contract period.

Despite this, the Supplier runs the risk that:

- The actual prices for electricity during the period of the contract will vary from his predictions
- The actual amounts of electricity demanded in each half-hour will vary from that predicted by the Supplier

In short, the Supplier is exposed to the risk that the money he spends to buy electricity on behalf of a customer will be different to that which he receives from the customer. In the worst case, the Supplier will lose money as the cost of supplying the customer exceeds the revenue from the contract.

As explained above, the Supplier would generally not want to make a larger profit on a contract than he had predicted either, other than to cover an equal and unexpected loss elsewhere.

The small minority of customers with Pool price related contracts, present less of a risk, since, depending on the contract, the Supplier passes on the fluctuations of the Pool price to the customer.

The Use-of-system charges usually present little or no risk to a Supplier, since they are almost always passed on to the customer.

4.2.1 Fluctuation of Electricity Price in the Pool

Just like the movements of financial markets, it is impossible to predict Pool price fluctuations perfectly, due to the occurrence of entirely unpredictable events. These might include a significant reduction in the availability of imports on the French inter-connector, or a large British power station being taken off-line for the repair of an unforeseen fault. Figure 3 gives a typical example of the variations in Pool price from day to day.

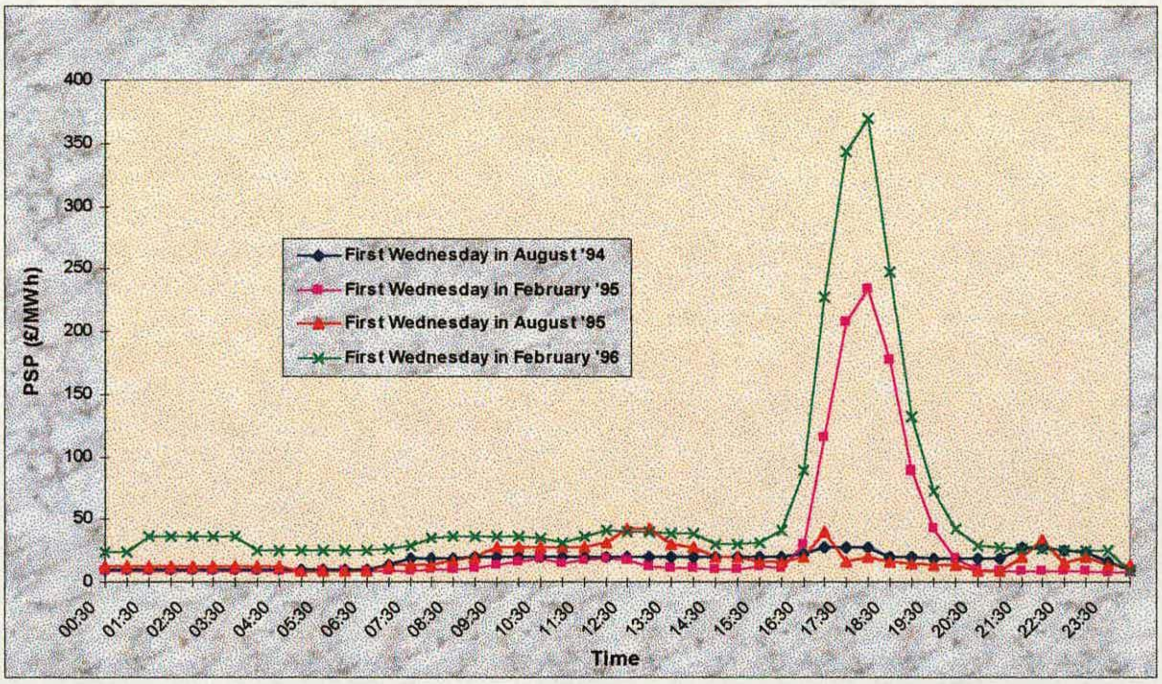


Figure 3 Example of Pool Selling Price Variation. Source: The Financial Times

4.2.2 Fluctuations in Customer Demand

Fluctuations in customer demand are also partially unpredictable. The use of heating or air conditioning plant is usually connected with weather patterns, which are themselves difficult to predict. Unexpected changes in working patterns for industrial or commercial customers, such as increased production to meet rising orders, or changes is employee shift schedules, would contribute to deviations of actual usage from their Supplier's predictions.

4.2.3 Fluctuations in Price in Combination with Fluctuations in Demand

One exacerbating factor is that the predicted demand has to be multiplied by the predicted Pool price in the tariff calculations. This can increase the effect of errors or deviations from either forecast on the outcome of the contract. This effect becomes worse, the more Pool price is correlated with the customer's demand pattern.

The Supplier needs to calculate a weighted sum to take into account both how much electricity a customer is expected to consume at each half-hour of the contract and what price that electricity is expected to cost at each half-hour. This tariff calculation is shown in Equation 1.

$$Tariff = \frac{\sum_{t=t_1}^{t=t_2} \left(Pool_t \cdot Demand_t\right)}{\sum_{t=t_1}^{t=t_2} \left(Demand_t\right)} \qquad t_1 \le t \le t_2$$

Where:

$Pool_t$	is the Pool price during period t; in *£/MWh*
$Demand_t$	is the maximum demand during period t; in *MW*
t_1	is the time at which the tariff comes into effect; in *hrs.*
t_2	is the half-hour before the tariff ceases to apply; in *hrs.*

Equation 1 The Tariff Calculation

The combined uncertainties from both the Supplier's forecasts of the actual consumption and the actual Pool price can cause even greater differences between the actual electricity cost to the Supplier from that which was projected.

Indeed, one tricky feature of pricing contracts is that both customer demand and Pool prices are to some extent correlated. For example, during a cold spell, both the prices for electricity *and* the amount that the customer consumes are likely to increase, as both the customer and consumers in general use more electricity for heating. If such cold spells are not predicted accurately enough, then the actual energy cost of that contract could be significantly different.

4.3 The Risk Premium

Normally, for accepting risk, the Supplier will expect some financial return from a customer. He will often charge a risk premium to the customer, possibly as a separate charge on top of the basic tariffs, or incorporate the risk premium within the tariffs. This risk premium then acts as a kind of insurance payment against the unpredictable deviations of price and demand from the Supplier's forecasts.

In a competitive Supply market, the Supplier has the incentive to keep the risk premiums as low as possible, by assessing risk exposure and adopting means to reduce it.

4.4 Risk Assessment

When considering a contract, the Supplier will calculate not only the expected cost of supplying the customer, and consequently the tariffs needed to be charged, but also try to evaluate how much the behaviour of the contract might vary, i.e. the probabilities of the contract making more or less than is expected.

The Supplier may consider a number of scenarios, each one represented by a different set of Pool prices and a different pattern of demand from the customer. The Supplier will then make a judgement as to the probability of occurrence of each scenario, before coming to a conclusion on the risk associated with each.

The Supplier may also use his experience of contracts with similar customers and their historical performance to help inform his judgement.

He may also use some popular risk measure, such as variance or one of his own design.

4.5 The Supplier's Attitude to Risk

As described above, dealing with risk is not simply about minimising it. Suppliers may chose to take on more risk in situations where the expected return is high. Generally, the Supplier needs to take a risk position that he is comfortable with and most successful Suppliers will have developed a strategy to manage their risk exposure.

4.6 Dealing with Risks

There are two ways in which the Supplier can deal with these risks, viz.,

- Decreasing risks by improving forecasts.
- Risk Management

4.6.1 Improving Forecasts

Time-series analysis is often based on identifying patterns within historical data to provide improved forecasts. The discipline also concerns itself with identifying causal links between variables, so that the fluctuations of one variable might be forecast based on a prediction of the movement of another and their proposed relationship.

Many techniques for time series analysis exist[23], including:

- FIR Filters
- Box-Jenkins
- K-d trees
- Piecewise linear interpolation

- Low-pass embedding
- Nearest neighbours
- Wiener filters
- Recurrent and feedforward artificial neural networks (ANNs)

For example, ANN's have been used to in an attempt to predict both Pool price[24] and demand[25].

In addition to pure numerical analysis, forecast data might be prepared using information such as expected changes in electricity consumption due to the introduction of new plant or changes in workplace practices, etc.

4.6.1.1 Patterns in Electricity Data

Much can be done by simple inspection of historical data to help predict the movements of electricity demand and price. Suppliers will be aware of the past behaviour of both the Pool price and its customers demand over the years.

4.6.1.2 Patterns in prices in the Pool

Examples of trends that occur in Pool prices were discussed in the last chapter in 3.3.

Two particularly unfortunate aspects of Pool prices are both the size and behaviour of the peak values that occur during winter days around the afternoon to early evening, especially weekdays. Many observers see this feature of the Pool prices as having been caused by the bidding strategies of the two largest generating companies, Powergen and National Power[26].

Peak prices are significantly higher than at other times during the day, see Figure 4, and thus contribute disproportionately to overall energy costs. The ratio of peak prices to prices during the rest of the day is often 3:1, and sometimes much more – as much as 10:1 in the winter. This is combined with the fact that peak prices show much greater variation than prices at any other time of day. This makes energy costs highly unpredictable. The prediction of these peak values is therefore both most important *and* most difficult.

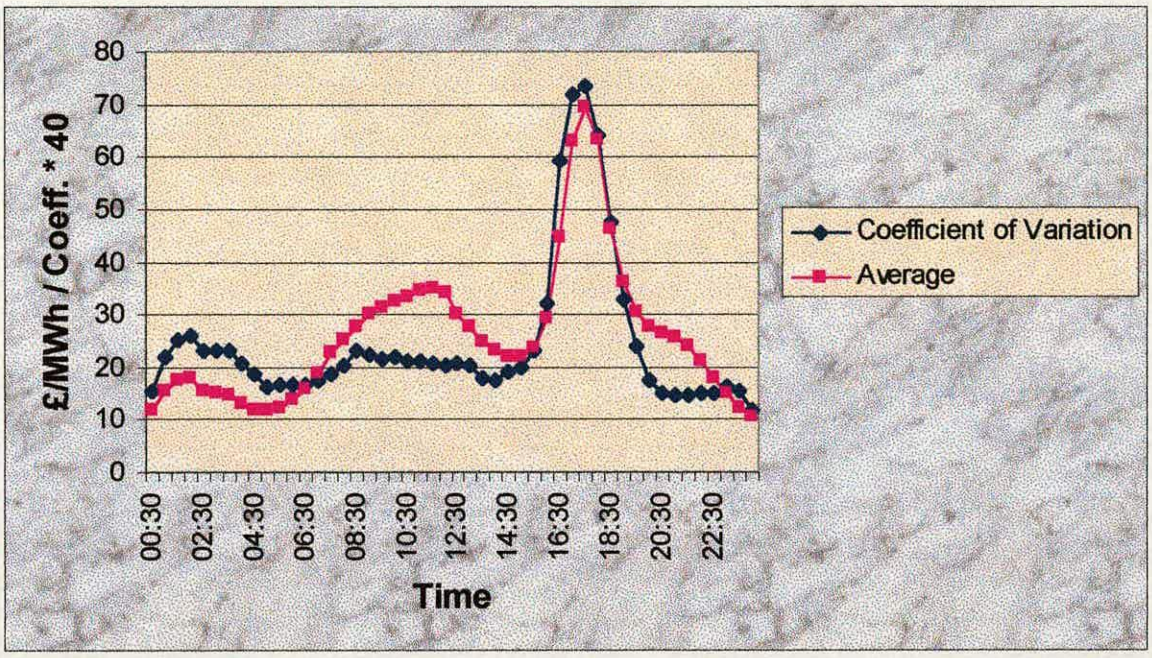


Figure 4 Pool Selling Price, Average and Coefficient of Variation, 1st April '94 to 1st April '97

4.6.1.3 Difficulties with applying Time Series Analysis

Time Series Analysis generally requires a lot of relevant historical data to provide accurate forecasts to find trends, patterns, and statistical relationships between variables, some of which might require an extremely long period of time to become evident.

Unfortunately, the Pool has only been operating for just over eight years, and the underlying environment that has determined prices has been evolving. The market for electricity has changed considerably:

- Pool Rules have changed.
- New industry members have joined and others left.
- Players have been adapting their strategies to new insights.

With all this change, it makes it difficult to identify trends in the data and the reasons for them.

Also, very little suitable data is yet available. For example, there are probably only two or three examples of a series of Pool prices for a wet Sunday afternoon in April – a slim basis for a thorough statistical analysis.

The usefulness of these numerical techniques is hampered by these facts and the results they provide are often inferior to those from a human expert's judgement.

As an example of the unpredictability of electrical demand, Figure 5 shows the effect on national demand of the screening of the England vs. West Germany World Cup semi-final in June, 1990. Electricity companies might have predicted some of this and bid into the Pool accordingly. Since Pool prices are determined a day-ahead, the actual cost of electricity for this day would in some way reflect the approximate schedule of this match. However, nobody, six months prior to the event, could have predicted its effect, let alone whether England would have actually reached this stage of the competition. It is unlikely that any Supplier would have included such a scenario in their pricing analyses for contracts agreed many months before.

Although one incorrectly forecast day is not going to affect the performance of a single contract significantly, a build up of these errors might.

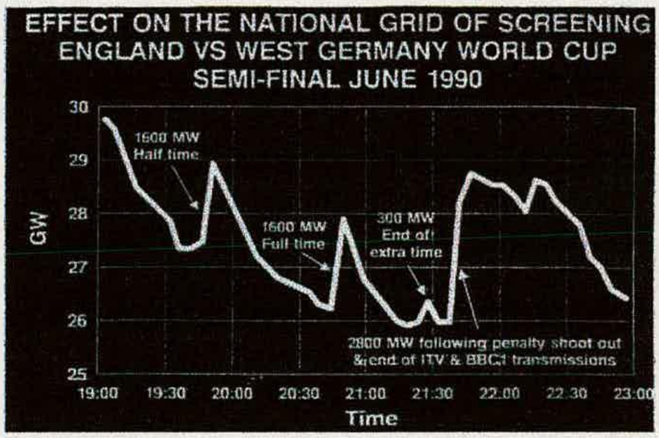


Figure 5 Example of the unpredictability of electricity demand

4.6.1.4 Patterns in Demand Data

Suppliers have gathered data over the years from half-hourly meters installed at their customers' sites. When forecasting electricity demand for a particular contract, they will draw upon data accrued from both that customer's site, if they have provided supply before, and/or data acquired from other similar sites.

However, particularly in the case of low demand consumers, such as domestic customers, half-hourly metered data is normally not available. In these cases, the Supplier will use a standard profile as a basis for his demand forecast. This standard profile will have been developed from research into a representative sample of such sites. This research may have been carried out in-house, or by a third party, such as the Electricity Association with its Load Research Group[27].

The Supplier must also take into account the structure of the tariffs to which the customer will be subject and consider how he will react to it. The customer may respond to the tariffs by shifting his demand away from periods during which higher tariffs are in force and into periods when lower tariffs are applicable. This will affect the customer's demand profile, which may, in turn, affect the performance of the contract in some way. The Supplier must be aware of the possibilities and their likely effect on the risk and return of a contract. This might involve modelling the behaviour of the client[28]. The Supplier must include this information in any sensible demand forecasts.

However, empirical studies[29,30] have shown that customers' responses to SToD rates are often limited. That is, customers fail to change their pattern of output significantly although the potential for savings in their costs for energy is obvious. The literature argues that this is because the customers' perceived adjustment costs, e.g. scheduling a new work shift in the evening or early morning to avoid peak price, outweigh the perceived benefits of such a shift in demand. Though these studies have gathered a considerable amount of data, no study to this date, as far as the author is aware, has conducted its survey within the UK environment where some customers are exposed to significant peak prices within their tariffs. Their results should therefore be interpreted with caution.

4.6.2 Risk Management

Coping with all this uncertainty requires risk management. The areas of risk management in electricity Supply include:

- Customer Portfolio Management
- Electricity Futures
- Embedded Generation
- Metering
- Demand-side Management

4.6.2.1 Portfolio Management

4.6.2.1.1 Gathering a Portfolio

In financial markets, if the pattern of return on two risky stocks is sufficiently uncorrelated, then the combined return of both stocks becomes less risky. The fluctuations tend to cancel each other out. Risk-averse investors prefer to hold a range of stocks whose returns are uncorrelated to the extent that their combined, portfolio, risk is much lower than any single stock. Thus, if investing in only two stocks, a sensible investor might prefer to hold stocks in a computer company and an ice-cream manufacturer, rather than two computer company stocks.

This technique is used for a variety of applications. It has been shown to be a useful tool in formulating strategies to develop optimal generating unit mix to reduce a nation's risk associated with the fluctuating prices of fuel[31].

It can also be applied to electricity contracts. By gathering together a large customer base, the Supplier can reduce his overall risk as variations from the expected behaviour of each customer cancel each other out.

The effect of Pool price fluctuations cannot be reduced using this technique, since this is a common component of every contract, although errors in different forecasts might go some way towards cancelling each other out. However, demand fluctuations are more unique to each contract. Their values will have some level of correlation with other demand patterns due to common weather patterns and national economic conditions, for example. However, there will be more local demand determining factors, such as the state of the local economy or changes in the working patterns for a factory, which would not correlate well with another contract.

4.6.2.2 Choosing the right customer

4.6.2.2.1 Historical Performance

Just as an investor can alter the performance of his portfolio by choosing the right stocks, the Supplier can improve the performance of his portfolio of contracts by carefully choosing with whom to trade. The Supplier needs to develop a system of grading the risk level that a customer contract might represent. One such method could be to examine the historical performance of contracts with that customer, and/or those with customers that have similar attributes, e.g. operate in the same industries, to determine how much the expected income from those contracts might deviate. This is analogous to the use of *Beta*[32] in equity markets, although information from customer's historical contract performance is likely to be more scarce.

4.6.2.2.2 Load Factor – A Basic Risk Coefficient

Another approach is to develop some numerical risk measure for customers. One such measure is *Load Factor* (LF), a dimensionless coefficient that can be used to rank customers in order of risk:

Load Factor = Average Demand/Maximum Demand

This metric provides a rough indication of how "peaky" a customer's expected demand will be; the flatter the demand, the higher the LF will be.

The use of LF has its roots in electricity network planning, and has been used to indicate how effectively installed plant is being used. Low LFs on a transmission line or of a power station, for example, indicate that power transfer or station output is volatile and the line or generation plant is not being used as effectively as it might be.

LF, however, can also be used a basic risk measure of customers demand patterns. Generally, customers with high LF present less risk to their Supplier. Since peaks in demand generally coincide with peaks in Pool price, income from contracts with customers with low LFs is generally more sensitive to movements in Pool price than those with high LFs. The former's demand is generally more biased towards periods of higher and more volatile Pool price.

LF may not be used ubiquitously for this purpose, nor will it be relied upon solely as the only measure of customer risk when it is used, but it is certainly a well known and well understood quantity in the industry.

4.6.2.3 Electricity Forward Agreements

One technique for reducing risk is to use some financial instrument. Commodity markets, particularly, have long since traded such derivatives to reduce the risks of both buyer and seller. These derivatives put limits on the prices that the buyer and seller can trade goods at between two agreed dates. There are four basic types:

- Price floor
- Price cap
- Fixed-price, or *strike price*
- Price Band

This could, for example, help a farmer plan his future revenue from a crop that has yet to be harvested, or perhaps even grown.

Such contracts are know as *Contracts for Differences* (CfDs) and also exist in the electricity market. Suppliers can use such forward agreements to purchase blocks of electricity at a set price. Used sensibly, this can reduce the Supplier's exposure to fluctuations in the actual prices for electricity in the Pool.

A CfD is an arrangement in which one party enters into an agreement with another to supply a particular demand pattern for a fixed period of time at a negotiated price. The demand patterns can have a constant or flat MW curve or a shaped MW curve. The vendor sells to the Pool as usual. The buyer also buys from the Pool as usual. However, the contract forces one party to reimburse the other depending on the shift of the Pool price away from the agreed price(s). In a two-way contract with a single strike price, if the price in Pool rises above this strike price, then the vendor pays the difference to the buyer. On the other hand, if the Pool price drops beneath the strike price, the buyer pays the vendor the difference. In this way the contract provides a predictable transaction. These contracts can also be just one-way, where the agreement simply sets in place a price floor or cap that is invoked if the actual Pool prices dip below or rise above that figure respectively. Generally the party which gains the benefit from the one-way agreement pays an up front premium for such a deal. Figure 5 depicts the four types of agreement listed above.

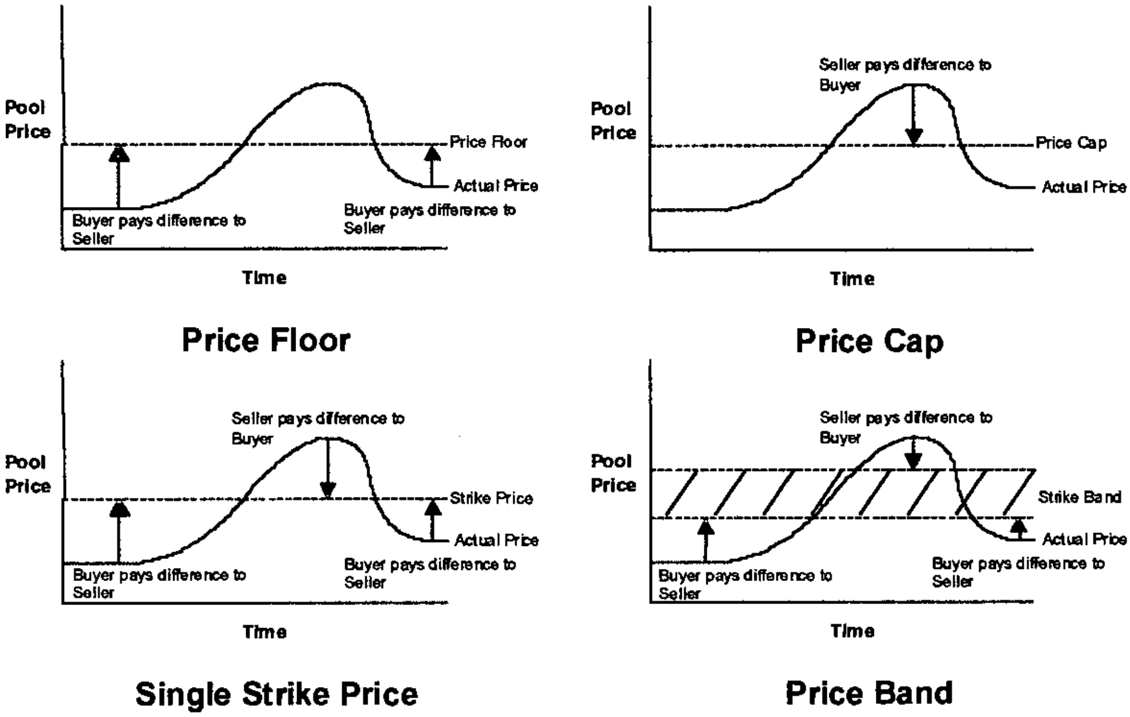


Figure 5 Examples of different one-way and two-way CfD arrangements

CfDs can be arranged in two ways:

- Directly between two industry players
- Via an intermediate broker

The second method has two main advantages for the prospective buyer or seller:

- The broker works on their behalf to match their bid with another party
- The transaction is anonymous

The *Electricity Future Agreements* (*EFA*s)[33] market, run by *GNI Ltd.*, provides this brokerage service[34].

EFAs are bilateral outright ("two way") CfDs with settlement weekly based on the average Pool price. The market provides an element of standardisation in that it provides a fixed structure for all contracts, thus promoting mutual understanding, efficiency, and therefore liquidity.

Although EFA's can be traded by any two parties involved in the industry, it is particularly useful for transactions between a Generator and Supplier. The arrangement is mutually beneficial as it allows the Generator to predict revenue more easily from his generating units, and the Supplier more easily predict the cost of Supplying electricity to their customers.

CfDs only exist for large volumes of electricity (typically > 1 MW) and simple supply shapes, where they make more economic sense. Presently, no such market exists for smaller contracts.

4.6.2.4 Embedded Generation

One way for a Supplier and customer to avoid Pool price is to use electricity generated from a local generating unit that is not bid into the Pool. Due to the nature of the Pool rules, only small capacity generating sets (< 50 MW) can be used for this purpose. These generating sets are known as *Embedded Generation*.

Such a set could be located on the customer's site, or elsewhere, in which case the owner of the wires connecting the site to the generating unit would generally be paid use-of-system charges.

The generating set could be owned by the customer themselves, for example, the plant run by The Boots Company on their Beeston site in Nottingham, UK[35], but in many cases it is leased by the Supplier, who may also operate the unit.

Depending on the contract, this arrangement provides the potential for both the Customer and Supplier to avoid fluctuations in the Pool price. However, other costs are incurred, such as:

- Initial capital costs
- Fuel
- Maintenance
- Operation costs and administration
- Depreciation

These all have to be taken into account when weighing up the benefits of such an alternative. Use of such local generation also introduces the user to a different set of risks, including:

- Fluctuating price of fuel.
- Reliability of plant.
- Efficacy of maintenance service.
- Effectiveness of despatching strategy.

Many small generating stations are Combined Heat and Power (CHP) units running on natural gas, but the use of such fuel exposes the user to the variations in its price. Presently, this fuel can be purchased on low risk, long-term contracts. Typically, the payback period for a CHP installation is between 3 to 5 years[36]. Traditionally, CHP plant has only been suitable for customers with maximum demands of over 40 kW, like a hotel with at least 50 rooms and a swimming pool. However, recent years have seen the development of Micro-CHP, with outputs of under 5 kW suitable for domestic application[37]. Thus there is now a solution for any size of customer.

A despatching strategy has to be developed to decide when the unit should be scheduled. For example, the plant might run all the time, or be used solely during expected peak Pool price periods. Clearly units are generally more economic to run during periods of high Pool price. However, it must be borne in mind that repeated starting and stopping of such plant puts extra stress on them, and will have a detrimental effect both on the longevity of their operational life and on the cost of maintenance. This, in turn, must be taken into account if the benefit from such plant is to be properly analysed.

The differences in the risk exposure, as well as the differences in costs have to be taken into account when deciding whether it is beneficial to the parties involved to employ such an option.

4.6.2.5 Metering

Remote metering[38] of electricity demand provides Suppliers with a means of not only settling a contract at the end of its period but also monitoring the performance of a contract during its time of operation. Although this will generally not help change the performance of the contract, since generally tariffs have already been agreed, the Supplier can often be forewarned as to significant deviations from its expected behaviour. They may then be able to take some measures to limit its impact, by, for example, taking out new EFA cover.

Half-hourly metering of a customer provides the Supplier with very useful information, but its cost has been seen to be too great to be used for every consumer, at least initially, as the industry matures and systems become more standardised and cheaper. This is particularly true of those with low electricity demand, e.g. the average domestic consumer, where the cost of a half-hourly meter and the marginal cost of the necessary communication systems are a much more significant part of the overall cost of such electricity contracts. The Supplier in these cases uses standard profiles to calculate tariffs for each class of low demand consumer. However, the Supplier might install half-hourly meters in a representative sample of these customer's sites to improve the quality of his customer data.

4.6.2.6 Demand-side Management

Demand-side management was original conceived to decrease end-user electricity demand in order to cut overall demand growth, leading to a reduction in the need for further investment in generation and distribution plant. Although, in the search for profit, it is often in the interest of a Supplier to sell more electricity rather than less, it is sometimes advantageous for an electricity utility to help reduce end-user demand. On occasions, the avoided cost of the extra investment required to meet demand is often greater than the potential profit from greater electricity sales. This is often called *Least Cost Planning* (LCP)[39]. The lack of vertical integration in the UK market makes it more difficult for electricity companies to make such optimisations. Indeed, the recent announcement[40] that all Regional Electricity Companies may be split up into distribution businesses and Supply companies undermines the potential of LCP further.

Whatever the future of DSM in general, it does have at least one other useful application. Consistently reducing or shifting away a customer's demand from the volatile peak Pool periods will reduce the level of risk that contract represents to the Supplier.

Ways in which such a shift or reduction might be organised include:

- *Contractual arrangements between Suppliers and Customers* to provide the latter with strong cost incentives to reduce their demand during peak periods.

- *Load management carried out by the Supplier.* These contracts are often conceived differently in that instead of being simply responsible for the supply of electricity, the Supplier becomes an Energy Services Company (ESCO)[41]. The contract, for example, might dictate acceptable levels of air conditioning, heat and/or power that the Supplier is expected to deliver. The contract might stipulate how the customer would be compensated if these agreed levels were not met at any stage.

The latter scheme is becoming a popular concept as it provides the Supplier with the flexibility of managing the customer's energy requirements in any way they see fit. This might include the use of on-site generation, and/or energy efficient plant that could be leased to the customer for the period of the contract. The capital costs and/or payback period for such plant might be prohibitively large for a customer to have access to it with any other arrangement.

4.7 Conclusions

This chapter has discussed some of the risks faced by electricity Suppliers operating in England & Wales with regard to the fluctuating price of electricity in the Pool. It has also discussed methods that Suppliers can employ to manage their risk exposure. Risk management in electrical supply can employ a whole host of different techniques that can be tailored to a Supplier's specific needs. The large range of techniques available add to its flexibility and hence its usefulness.

The ability of a Supplier to manage risk is a key component of his competitiveness. As the industry matures and becomes more able to deal with risk, the customer should benefit from improved value for money in his purchase of electricity.

Chapter 5 ESIPRAS

5.1 *Introduction*

In this chapter, the case for a Decision Support System for electricity contract analysis is discussed. The aims and design of the software are then described.

5.2 *The Case for 'ESIPRAS'*

5.2.1 Decision Making in Electricity Supply

The day-to-day decisions a Supplier needs to make might include:

- Choosing between a number of different contracts with customers to find the ones with the best return versus risk trade-offs
- Pricing a contract whilst incorporating a high enough margin to act as an insurance against the risk that the Supplier perceives the contract may represent
- Determining whether an on-site generation facility would lower the cost of electricity to the customer
- Determining whether he could offer a customer cheaper tariffs than a competitor whilst meeting profit targets
- Deciding whether a contract would be of low enough risk to be an acceptable prospect

In order to make such decisions, the sales analyst may need to consider the strategic goals that the sales operation is trying to reach[42]. For example, the company may have decided to take on less profitable contracts in order to meet a market share goal.

5.2.2 The Electricity Sales Analysis Process

One common component required to make most of these decisions, is the need to measure how much money contracts with customers might make or lose. As shown earlier, this is a function of the:

- Customer's forecasted demand
- Forecasted Pool prices
- Pattern and level of demand the customer actually uses
- Actual Pool prices

If the Supplier is trying to beat a quote from a competitor, this is also a function of the:

- Target tariffs to beat

In the process of reaching a decision, the analyst may develop:

- Forecasts for customer demand and Pool price
- Tariff structures, the pricing schemes employed to charge different rates for electricity at different times
- Different scenarios of Pool price and customer demand

5.2.2.1 The Forecasts

Often the analyst begins with basic forecast data for the Pool Price and the customer's likely pattern of demand, often as a half-hourly profile. Usually this data is prepared by "rolling forward" a previous year's data, adapting it by shifting it along the calendar to line up weekends and swapping days to take account of differences in public holiday dates. New customers will often come with their historical data to help with this forecast. In fact, Supply companies are legally bound to pass on all recorded demand data if the customer switches Supplier. This data may come as a detailed half-hourly recording of their past consumption, or as monthly averages.

Forecasts could also be prepared using a variety of time-series analysis techniques, as discussed in the last chapter. There are no prescriptive methods for creating forecasts.

When half-hourly data is not available, a customer profile from the Supplier's database may be used as the basis for a forecast. This profile may have been sourced internally from a past or existing, similar customer, or from outside, for example, from a demand research organisation. This data may then be modified to take into account differences between the new customer and the profile. The Supplier can use monthly average figures to scale the profile to fit that information. He may also use details like the number of employees or size and number of plant to adapt his forecast. The data can also be manipulated to provide consistency with historical statistics such as load factor, the percentage of night demand vs. day demand, etc.

The forecasts are created with a list of basic assumptions. For example, for a Pool Price forecast, the assumptions might include that the annual growth in electricity demand would remain static. The analyst would then have the option of modifying the data to take into account the effect of a decrease in annual consumption by perhaps decreasing its volatility to reflect this possibility.

These methods often provide sensible forecasts. From these forecasts, a sales expert can examine further possibilities.

5.2.2.2 Tariff Structures

A customer usually pays for consumption of electricity based on an agreed tariff structure. This structure stipulates what tariff should be employed for the use of electricity depending on when it is consumed. The tariff structures usually contain one or more tariffs that come into effect within distinct periods. For example, one simple tariff structure might contain two tariffs, one for night consumption and one for day consumption. Often the tariff structure may incorporate a 'peak' tariff that is only applied during winter afternoon/evening's when Pool price and demand are both higher and more volatile.

The analyst generally prices these tariffs in order to recoup the cost of energy he predicts will be used during their period of operation. Administrative costs can be charged separately and profit can be gained through adding a simple margin to the total contract. Choosing the tariff values is therefore critical, since the financial performance of the contract is highly dependent on them. The analyst must usually not set tariffs that, once the contract has finished, have not recouped the total cost of electricity supplied to the customer. The analyst may quote a range of tariff structures and tariffs in order to reach an agreement with a customer.

5.2.2.3 Different Scenarios – *What If?*'s

The analyst needs to examine numerous scenarios in order to develop a sensitivity analysis of a contract. He also needs to weigh up the likelihood of each scenario occurring so that he can estimate the level of risk to which his company is exposing itself if it were to sign a contract with the customer.

Although the analyst could consider many thousands of possible scenarios, he is most likely to be concerned with:

- The scenario in which the contract would make the most money or the least loss.
- The worst possible scenario, the scenario in which the contract would lose the most money, or make the least profit.
- The most likely scenario

He is likely to price for the most likely scenario, but may consider adding a risk premium to the margin or tariffs if the other scenarios have a high enough probability of occurrence.

The analyst could consider a number of Pool price and demand consumption scenarios to identify if there is a point at which a customer's contract might become unprofitable given a single set of tariffs that are chosen to beat a quote from a rival Supplier. He might perhaps decide that because of some ruling of the Electricity Regulator, price volatility might increase to a certain degree. He will want to examine how this will affect the performance of the contract.

Indeed, the analyst needs to consider a multiplicity of factors that might affect both the customer's electricity consumption and the Pool Price.

There are no cut-and-dried prescriptive methods of scenario generation, since it depends heavily on an analyst's own judgement.

This scenario analysis process is depicted in Figure 6.

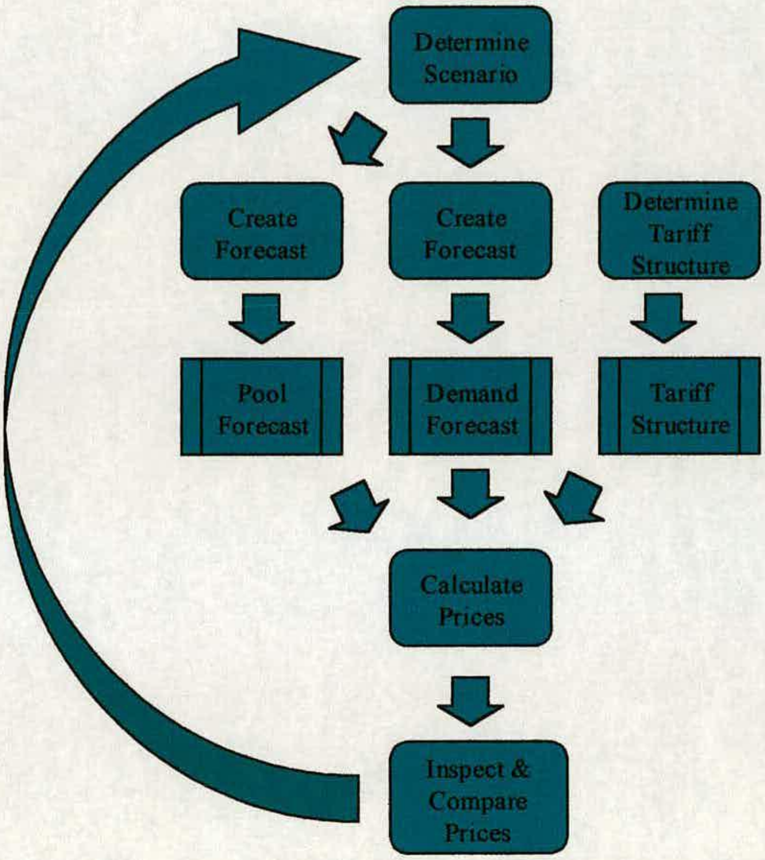


Figure 6 The Sales Analysis Process

5.2.2.4 On-site Generation

Normally, as explained earlier, all electricity supplied to a customer is bought from the Pool. The Supplier may want to examine the possibility of providing an on-site generation facility for the customer in order to divert demand from the grid during periods of high Pool price. In this case, the analyst will want to calculate the costs involved in such an exercise and the cost of grid electricity that is avoided to assess the feasibility of such a project. To determine this, the analyst must be able to model the capital and variable costs of the facility and the effect on the demand from the grid of a suitable despatch strategy. In reducing the customer's electricity costs, the Supplier might hope for some financial return by charging the customer for this service, thus offsetting the lower turnover of the contract. This extra charge might be included in an increased administration charge or an increased margin.

5.2.3 The Calculations - The Case for a Decision Support System

To make any of the decisions cited above, and to do so on the basis of thorough analysis, the sales analyst needs to make many repetitive, laborious pricing calculations and needs to create and keep track of many scenarios. He also needs to be able to compare data sets and switch between them quickly and easily. This is the sort of task for which a Decision Support System (DSS) is very suitable.

Such a system could be designed to allow the user to manipulate tariff structures, demand data and Pool Prices. It could take away a lot of the time-consuming calculations required to make judgements on a contract so that the user is given more freedom to concentrate on scenario creation and exploration and can provide customer quotes and feedback faster.

The system could help the user keep track of different scenarios and their affect on the performance of the contract. It would require the same basic forecasts used in the conventional analysis, but would allow the user to manipulate these forecasts much more quickly giving the user time to examine more possibilities.

Described below is the development of a DSS for Electricity Sales, called the *Electricity Sales Integrated Price & Risk Analysis System* (*ESIPRAS*).

5.3 The Benefits of Decision Support Systems

Turban provides a definition of a DSS[43] that includes:

> *"A DSS is an interactive, flexible, and adaptable Computer Based Information System, specially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, it provides easy user interface, and it allows for the decision maker's own insights."*

A more classical definition is[44]:

> *"Decision support systems couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions."*

Turban also cites the major benefits of a DSS[45]. These include the:

- Ability to support the solution of complex problems.
- Fast response to unexpected situations that result in changed conditions.

- Ability to try several different strategies under different configurations, quickly and objectively.

- Cost savings. Application of DSS can result in considerable cost reduction, and/or the reduction of costs associated with wrong decisions.

- Objective Decisions. The decisions derived from a DSS are more consistent and objective than decisions made intuitively.

- Improved managerial/analyst effectiveness, allowing managers/analysts to perform the task more quickly with less effort, leaving more time for quality analysis.

The design of *ESIPRAS* has attempted to provide a DSS with which the electricity sales analyst can pursue typical decision goals, as listed above, efficiently and accurately. The design attempted to provide enough flexibility to allow the analyst to use the DSS for a wide range of tasks whilst not forcing the analyst to approach each problem in a rigid fashion.

5.4 How 'ESIPRAS' was Created

5.4.1 Managing the Development of ESIPRAS

The system was developed in conjunction with sales analysts at a leading UK Supplier. At the beginning of the project, an overall time-scale was agreed, as shown in Figure 7. The planned complexity of the system was to be kept within the limits of what was felt practical given this period. Regular development meetings were held together with experts from different parts of the sales team, between which agreed milestones were met, the results of which would be discussed at the following meeting. At each meeting, the parts of the system would be demonstrated. In this way, most errors in design or implementation could be discovered quickly and rectified within one or two meetings. Once the system had reached an agreed level of completion, trials were conducted by the sales team to uncover any remaining design errors or bugs that could then be corrected.

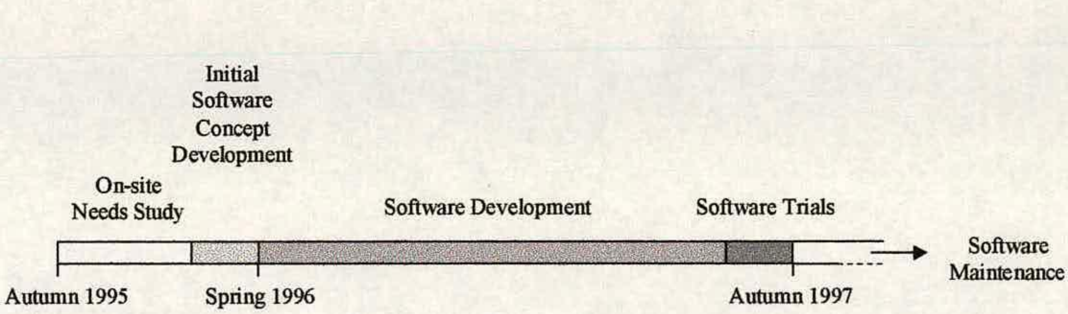


Figure 7 Actual Development Schedule

5.4.2 On-site Needs Study and Software Concept.

Interviews with all key staff in electricity sales were carried out to determine a business need that might be fulfilled with novel Decision Support System. Ideas from different staff were drawn together to form the software concept. This concept was developed into a set of requirements.

5.4.3 The Design Paradigm

ESIPRAS was designed using *Borland Delphi,* a Rapid Application Development (RAD)[46] Computer Aided Software Engineering (CASE) tool. The software development cycle employed is depicted in Figure 8. This includes elements of both Incremental and Evolutionary[47] design principles, both of which are particularly suited to RAD. *ESIPRAS* was built incrementally using components that were developed in an evolutionary fashion, that is, development began with a set of initial goals and design principles and progressed through a rough architectural design into cycles of design, implementation and testing before final delivery. The designs of components were constantly adapted in the light of experience and new ideas were added to the feature list if thought appropriate.

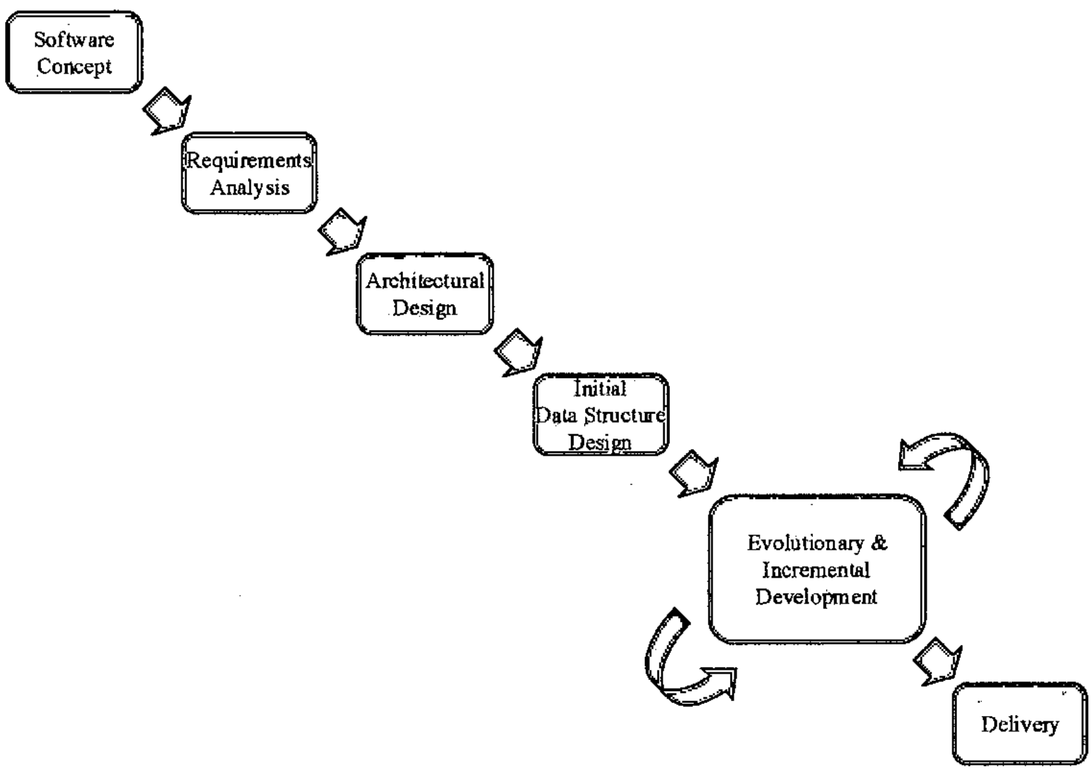


Figure 8 Software Development Cycle

5.4.4 The Goals of 'ESIPRAS' – Requirements Analysis

5.4.4.1 What *'ESIPRAS' was* intended to

The development of the system set out to provide a DSS with the following facilities:

1. A price calculator that would formulate a set of prices, based on a forecast of demand, a forecast of expected Pool Price, and the desired Tariff Structure.

2. An ability to import and hold a number of forecasts and to present the user with an indication of the forecasts held within the system.

3. An ability to allow the user to adapt forecasts in sensible ways to provide alternative *What-If* scenarios for price comparison and contract feasibility.

4. A price analyser, that would allow the user to inspect the effect of different sets of tariffs on the performance of a contract under different scenario conditions.

5. The ability to import, create, and edit a number of tariff structures that could be employed to generate a wide variety of prices.

6. The ability to present any numerical data, such as forecasts and prices, in a flexible on-screen graphing system that had the ability to print. This would allow the analyst to visualise data so that he could identify features that might help an analysis.

7. *ESIPRAS*'s use was to be limited to the analysis of contracts within the English & Welsh market. It was not intended to be used for analysing contracts where Pool price would be less relevant, e.g. Northern Ireland or Scotland. In addition, it was not intended to assess credit risk, i.e. the ability of a customer to pay his Supplier and meet his contract obligations.

Further design specifications included:

8. The system would work satisfactorily on a PC with an Intel 166 MHz processor, or better.

9. The system would function on a PC equipped with either *Windows 95* or *Windows NT* 4.0.

10. The system would provide an easy-to-use interface suitable for a 15-inch screen or larger.

Further features could be added later in the design period as appropriate.

5.4.4.2 What 'ESIPRAS' was *not* intended to

ESIPRAS was not intended to forecast demand profiles or Pool Prices. It was realised early on in design specification that this was best factored out of *ESIPRAS* and the responsibility of forecasting should remain with experts in each field. No attempt was made to encapsulate the forecasting knowledge of these experts. Forecasting time series is complex and it was felt that *ESIPRAS* would not easily be able to provide a flexible enough environment to incorporate all useful innovations in this area within the period of its use. By ensuring that the system could import forecasts ensured that it could use the results of any forecasting method, and ensured that the time saved through not implementing any forecasting system, could be spent developing other important parts of the system.

5.4.5 Architectural Design

Architectural design began by creating a data and function flow representation, shown in Figure 9, from the Sales Analysis Process depicted in Figure 6. Each functional component of the system was to take the form of a system screen. Each of these screens was used to carry out a logical function or group of functions that represented a step in the sales analysis process. For example, the calculation of a set of prices, given a particular Pool price scenario, a particular demand profile scenario and a particular tariff structure, was carried out on one screen, the *Price Editor*. Other screens were used to display the price information calculated using this screen, but the source data and the pattern of prices were chosen here.

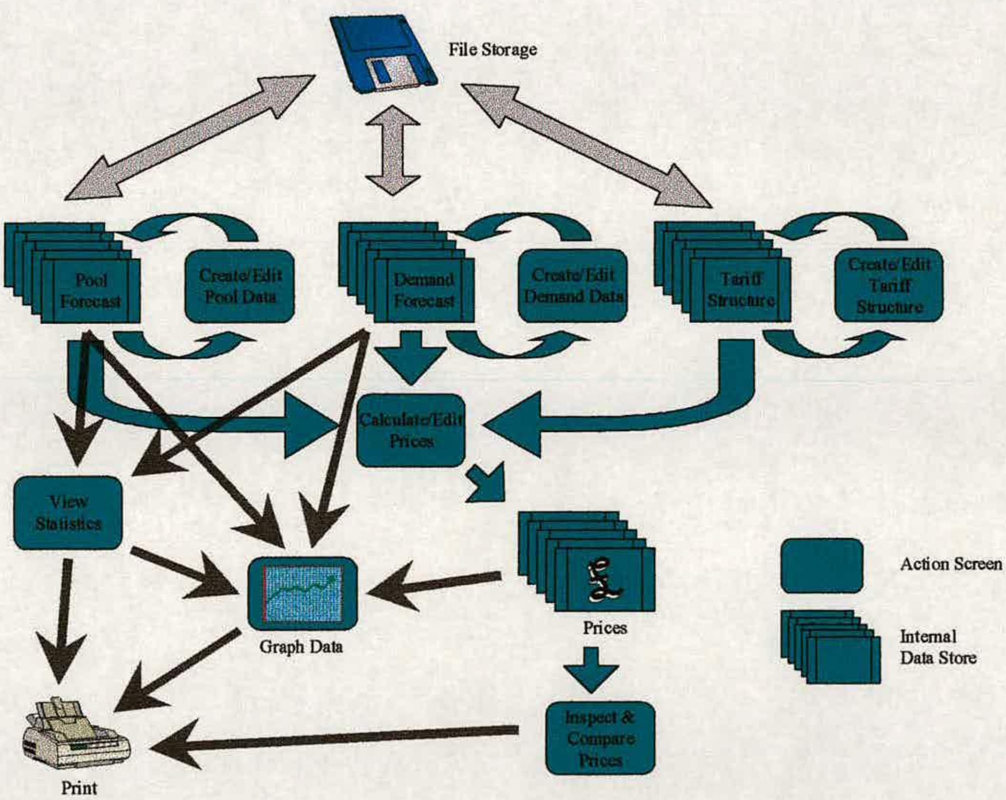


Figure 9 Function and Data Flow Representation

5.4.6 Initial Data Structure Design

Data structures were created to represent the different objects within the Sales Analysis Process. These data structures included ones for representing Pool data, demand data and tariff structures. Each data structure contained all the relevant attributes to specify completely an instance of a data object. For example, the data structure for a demand data scenario included attributes, amongst others, for customer name, number of days of demand data, source filename and the demand data itself. The data structures were kept in a separate software module from the rest of the code as they were considered to be logically distinct. This allowed for quicker and more effective maintenance of their code.

5.4.7 The Incremental & Evolutionary Development Stage

As described earlier, the system was developed both in an incremental and evolutionary fashion. The system was built incrementally by building stage-by-stage each functional component or screen. Components on which other parts of the system would depend were built first. Each functional component was evolved in response to feedback from development meetings.

Once data structures had been developed to an initial level of satisfaction, work began on the *Main Screen* that the user is presented with on starting up the system. Development then began on allowing the user to import data into instances of the data structures for use in analysis. Figure 10 depicts the progress of system development from the beginning of the main coding stage of the development cycle.

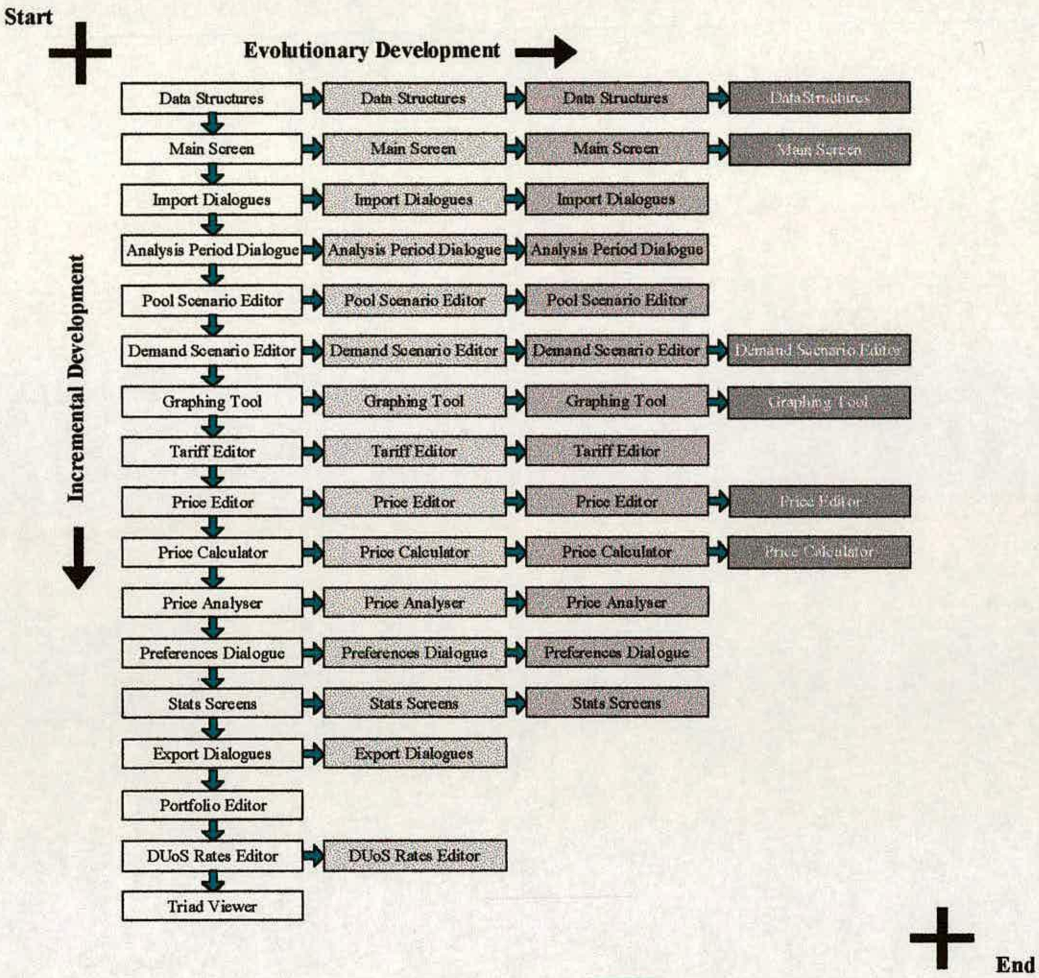


Figure 10 The Incremental and Evolutionary Development of ESIPRAS

5.4.8 Employing Object Orientated Principles

Object Orientated (OO) principles of software design were employed where it was felt practical and useful. Inheritance, polymorphism and code re-use were all employed to speed up the development process and create a robust system. There are those software engineers who advocate the strict use of OO principles above all other considerations, but there are those who believe that it is has not proved to be the panacea for software development as most experts hoped it would[48]. On balance, the author opted to employ OO design when it was thought appropriate.

5.4.9 The User Interface

Particular attention was paid to *ESIPRAS*'s user interface. All common components of the *Windows 95/NT* interface such as list boxes, buttons, radio buttons, dialogue boxes, etc., were utilised to create a friendly and easy-to-use environment for the end-users. The layout and behaviour of the interface, too, were based on other common applications, so that users' expectations and intuition would be harnessed and not be undermined.

5.4.10 OLE!

One major example of code re-use in the development of *ESIPRAS* was the employment of another application to help import data. The demand and pool data both came in the form of *Lotus 1-2-3* spreadsheet documents. The author had the option of writing some code in order read these files directly, decode their contents and convert the data into an instance of an internal object. This would have produced some quite complex, difficult-to-maintain code that would have required expert knowledge of the *Lotus* spreadsheet file structure and could have taken a significant amount of time to design. The results of this code might easily be prone to error, especially if the code had omitted special cases that were not picked up in testing. The author would also have had to be written almost totally new code to import data from any other spreadsheet file types, such as *Microsoft Excel* worksheets. A method was sought of utilising work already completed elsewhere. The solution lay in remotely interacting with a spreadsheet program, in this case *Excel*, using a new (at the time of writing) interface technology known as *OLE automation*. This allowed *ESIPRAS* to start up *Excel*, ask it to load a particular file, and extract data from the spreadsheet file by remotely inspecting cells within the spreadsheet document. As long as the data was kept in standard places within the spreadsheet file, this would enable *ESIPRAS* to access seamlessly both *Lotus* and *Excel* worksheets.

5.4.11 Choosing the Development Language

Several criteria were used to choose the development language for *ESIPRAS*. These included, in a rough order of importance:

1. Performance of compiled code
2. Facilities provided by the language
3. Quality/ease of use of the development environment
4. Cost of the development product
5. Potential for development language to increase the range of skills of the author

At the time, it was clear that there were indeed 4 main language options, all of which were well supported for development on the PC:

1. C++
2. Borland's *Delphi*
3. Microsoft's *Visual Basic*
4. Sun's *Java*

5.4.11.1 Performance of Compiled Code

Early in the development process, it was anticipated that *ESIPRAS* would be required to carry out a lot of floating point intensive calculations. For example, in order to calculate a set of prices, *ESIPRAS* would have to multiply a large array of Pool prices by a large array of Demand values. As an example, consider a simple case where an analyst is asked to calculate a single unit price for electricity, so that it recoups the cost of electricity for a customer over one year. Recall the standard tariff calculation formula from the last chapter:

$$Tariff = \frac{\sum_{t=t_1}^{t=t_2}\left(Pool_t \cdot Demand_t\right)}{\sum_{t=t_1}^{t=t_2}\left(Demand_t\right)}$$

A typical year has 365 days and there are 48 half-hour periods in a day. Thus, there will be 365 by 48 or 17520 multiplications, roughly double that number of additions (there is one less addition above and below the line), and one division. This gives a total of 52,559 calculations for one price.

These calculations would have to be carried out within a time acceptable to the final user of the system. This demanded a language capable of producing reasonably fast code.

One design aim was to ensure that all calculations could be carried out within 5 seconds on the target PC (One equipped with an Intel 166 MHz processor).

Java was ruled out at this point. It is a generally a run-time compiled language and is thus much slower than the other three. At the time of writing, there are currently a number of Just-In-Time (JIT) compilers emerging for *Java* which intend to improve its performance, but at the outset of development these were not available.

The other three languages, *C++* (in its many varieties), *Delphi* and *Visual Basic* all provide some level of executable compilation.

However, the author was concerned that *Visual Basic* would generate code that was too slow for this application, since it was known to have a fairly basic compiler. To ascertain this, the author decided to test the feasibility of using *Visual Basic* by devising a small program that would represent a typical, but quite demanding, operation in *ESIPRAS*. The operation chosen was that of importing data. The program created was designed to import Pool price data from within a spreadsheet file into an array of floating point numbers in memory. This was achieved by copying the text of a spreadsheet document containing the data into the operating systems clipboard and then processing this text to extract the floating point numbers. The program did indeed carry this out successfully, but even after a lot of optimisation, still took several minutes to process a year's Pool price data, a typical amount of data which *ESIPRAS* would be expected to process. It was felt that this would be unacceptable from an end-user point-of-view, as users expect operations of this sort to be complete within a few seconds at the very most. Therefore, *Visual Basic* was ruled out.

5.4.11.2 Facilities provided by the language

At the start of development, it was decided to use an Object Orientated (OO) design methodology. This offers many advantages. OO design methodologies aim to[49]:

1. Reduce costs, especially software maintenance and cost of future enhancements.

2. Reduce development time.

3. Increase software reliability.

4. Match users' model of the world so,

- Requirements are captured more easily and accurately.

- System can be altered easily to track changes in user requirements.

All the languages listed in 5.4.11 allow development using OO techniques. However, some languages offer better implementations than others do. *Java* provides probably the best implementation but was discounted for the aforementioned performance restrictions.

5.4.11.3 Quality/ease of use of the development environment

At the time of writing, a new breed of Rapid Application Development tools was entering the market. Of the four languages considered, it was felt at the time that *Delphi* and *Visual Basic* offered the best development environments because of their ease of use and their automatic code generation facilities.

5.4.11.4 Cost of the development product

All the development packages supporting these languages could be purchased at a roughly similar price, so this was not a differentiating factor.

5.4.11.5 Potential to increase the range of skills of the author

The author had already gained much experience with *C* (not *C++* however) and felt that, in order to broaden his experience of computer languages, that *Delphi*, *Visual Basic* or *Java* would be better choices from this point of view.

5.4.11.6 The Final Decision

Visual Basic had had a good reputation for providing a good interface for development, and was therefore considered a good candidate for the development of *ESIPRAS*, but turned out to generate code that was too slow for this application. *Java* provided state-of-the-art OO and offered the ultimate in portability, since its code can run on almost any platform. However, as there was only a single target platform, the IBM compatible PC, this offered no advantage. *Java* produces much slower applications than all the other languages and so it was also discounted.

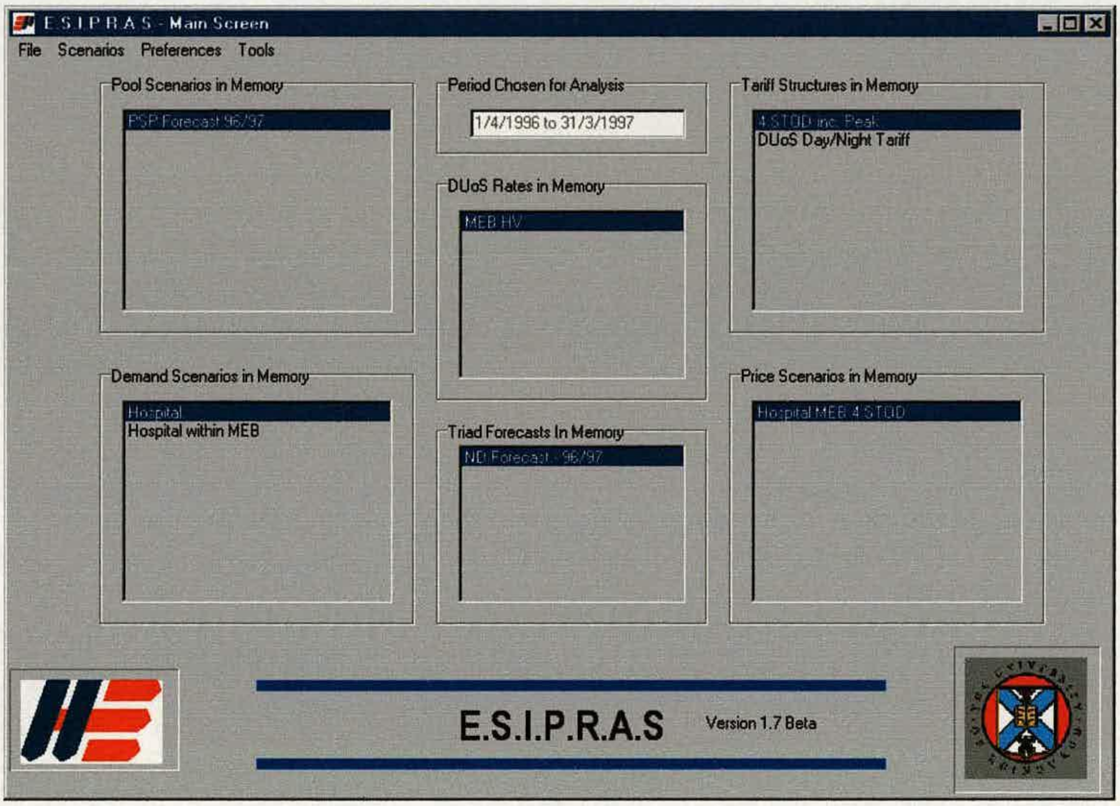
After taking in consideration all of the above, there remained two clear options, *C++* and *Delphi*. *Delphi*, at the time, offered a better, more advanced development environment. However, *C++* was slightly more powerful and generally created code that was a little faster than *Delphi* did. On balance, they both looked equally good candidates. It therefore came down to the final criterion, that the author wanted to broaden his experience. *Delphi* was thus chosen to develop the system.

Chapter 6 ESIPRAS: Software Guide

6.1 Introduction

This chapter provides a reference for all parts of *ESIPRAS*. The design and function of some parts of the system are discussed in greater detail in the next two chapters.

6.2 The Main Screen

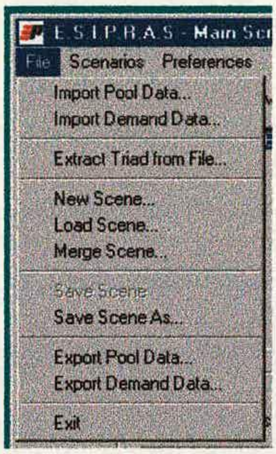


Screen Image 6.1 Main Screen

Screen Image 6.1 depicts the display that the user is presented with once the *ESIPRAS* has loaded. This screen informs the user what data is present in the system and forms the hub from which all facilities can be accessed. All other functions are accessible from the menus in the top left of the display.

These include the *File*, *Scenarios*, *Preferences* and *Tools* menus, shown in Screen Image 6.2, Screen Image 6.3, Screen Image 6.4, and Screen Image 6.5 respectively.

6.2.1 The File Menu



Screen Image 6.2 The File Menu

The *File* menu gives access to all the facilities in *ESIPRAS* provided to load or save data from disk:

- *Import Pool Data* allows the user to load Pool price data from a spreadsheet file (*Lotus 1-2-3* or *Excel*) providing the data is in the correct format; i.e. all the variables are in the correct cells. See Design Notes for this specification.

- *Import Demand Data* carries out the same action as the above, but for demand data, and is subject to the same limitations.

- *Extract Triad from File* calculates the triad periods within a demand profile from within a spreadsheet file according to the rules described in 4.1.2.1 and saves the dates and times in a triad scenario for use in costing use-of-system charges. The data within the spreadsheet file must be in a standard format as for loading demand data. See sections 6.7 and 8.2.1.

- *New Scene* clears all data from within *ESIPRAS*'s memory. A *Scene* is a file that is a snapshot of *ESIPRAS's* memory and includes all Pool price scenarios, demand scenarios, Price scenarios, Tariff Structures, Triad sets, DUoS rate systems and preferences settings. These can be saved and loaded and merged.

- *Load Scene* loads a new scene from disk and overwrites *ESIPRAS*'s present memory.

- *Merge Scene* adds the contents of a scene file from disk to the present scene in memory. This is useful if the user wishes, for example, to load a set of Tariff Structures or demand data in one go. It does not affect any preferences.

- *Save Scene* saves all data from within *ESIPRAS*'s present memory to disk, using the presently assigned name that is shown in the menu bar of the *Main Screen*. This option is not available if the Scene has not previously been saved.

- *Save Scene As* is similar to *Save Scene* but allows the user to specify a new name for the file that is saved.

- *Export Pool Data* allows the user to save a spreadsheet file of a selected Pool price scenario. This option will only be available if there is at least one Pool price scenario in memory.

- *Export Demand Data* allows the user to do the same for a demand scenario.

6.2.2 The Scenarios Menu

Screen Image 6.3 The Scenarios Menu

The *Scenarios* menu allows the user to access and edit the scenarios within *ESIPRAS* memory:

- *Pool* allows the user to access the *Pool Price Editor*, where Pool price scenarios in memory can be adapted and new ones created. This option is available only if there is at least one Pool price scenario in memory. The *Pool Price Editor* is explained below.

- *Demand* allows the user to access the *Demand Scenario Editor* where demand scenarios in memory can be adapted and new ones created. This option is available only if there is at least one demand scenario in memory. The *Demand Scenario Editor* is explained below.

- *Portfolio* allows the user to access the *Portfolio Editor*, where demand scenarios in memory can be combined or subtracted from portfolios. This option is available only if there are at least two demand scenarios in memory. The *Portfolio Editor* is explained below.

- *Tariffs* allows the user to access the *Tariff Structure Editor*, where the user can create new Tariff Structures, or alter existing ones. The *Tariff Structure Editor* is explained below.

- *Triads* invokes the *Triad Viewer* described below. It is accessible only if the user has already extracted at least one triad set from a demand file.

- *DUoS Rates* accesses the DUoS Rates Editor. This allows the user to specify distribution use-of –system charges.

- *Price* allows the user to access the *Price Scenario Editor*, where price scenarios can be adapted and new ones created. This facility is accessible only if there is at least one Pool price scenario, one demand scenario and the Analysis Period has been set in the *Analysis Period Dialogue* as explained below.

Screen Image 6.4 The Preferences Menu

6.2.3 The Preferences Menu

The *Preferences* menu allows certain global options to be set:

- *Set Analysis Period* allows the user to specify what period of the data is used for analysis. Its function is explained in more detail below.

- *Set Date and Time Prefs* allows the user to set certain global variables used in analysis. For example, these include the start and end dates of summer. Its function is explained in more detail below.

6.2.4 The Tools Menu

Screen Image 6.5 The Tools Menu

The *Tools* menu allows the user to access the various analysis tools provided by the system:

- *Data Statistics* allows the user to access the *Data Statistics Screen* that can be used to display the statistical attributes of any demand or Pool price scenario in memory. This facility is described in greater detail below. It is available only if there is at least one Pool price or demand scenario in memory and the Analysis Period has been set.

- *Compare Statistics* allows the user to access the *Compare Statistics Screen* that can be used to compare the statistical attributes of the demand or Pool scenarios held in memory. This is discussed below. It is available only if there are at least two demand or Pool scenarios in memory and the Analysis Period has been set.

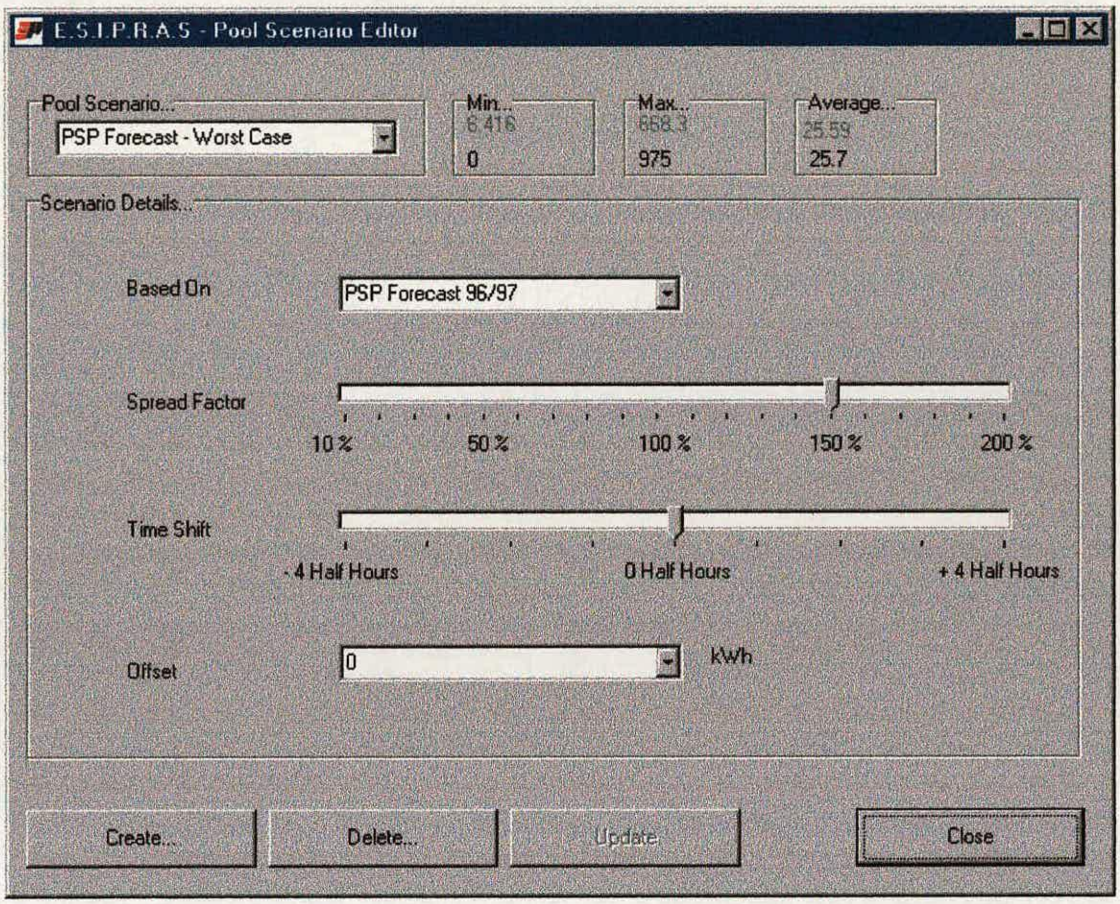
- *Risk Stats* allows the user to access the *Risk Stats Screen* that displays the supported risk coefficients for each of the demand scenarios in memory. This is described below. This facility is available only if there are at least two demand scenarios and one Pool scenario in memory and the Analysis Period has been set.

- *Graph Data* allows the user to access the *Graph Creator Screen* used to create graphs of data in *ESIPRAS*'s memory. This is explained below. It is available only if there is at least one Pool price or demand scenario in memory and the Analysis Period has been set.

- *Price Calculator* allows the user to access its namesake that gives a breakdown of the prices from a Price Scenario. This is described in more detail below. It is available only if there is at least one Price Scenario in memory.

- *Price Analyser* allows the user to access its namesake. This screen provides a comparison of two sets of prices, one from a Price Scenario and one entered by the user. This is explained in greater depth below. It is available only if there is at least one Price Scenario in memory.

6.3 The Pool Scenario Editor



Screen Image 6.6 The Pool Scenario Editor

The *Pool Scenario Editor* screen allows the user to create new scenarios from those loaded from disk. The list box at the top-left allows the user to select the Pool scenario to which he wishes to refer. When this list box is altered, the settings on the editor screen immediately reflect those attributes of the selected scenario. The editor also contains four buttons:

- *Create* generates a new Pool price scenario based on the Pool price scenario specified in the drop-down list box entitled *Based On*. The system presents the user with a small dialogue box where it asks the user to type a name for the new scenario. The system will not allow the use of a name that is a duplicate of one already used for a scenario in memory. The new scenario is adapted from the original by way of three settings:

  - ➢ The volatility of the new scenario is decreased or increased in accordance with the setting on the *Spread Factor* track bar. The system first calculates the mean value for each half-hour. It then calculates each value's difference from the mean for its half-hour. The system multiplies this difference by the Spread Factor and adds or subtracts it, depending on whether the original value was above or below the mean, to the half-hour mean to arrive at the new value.

This is intended to be a rough way of creating a Pool scenario with a general increase or decrease in volatility – see design notes in 8.4.

- ➢ The new scenario is shifted in time from the original in accordance with the setting on the *Time Shift* track bar. This is intended to be a rough way in which the Pool price peak periods can be shifted earlier or later in the day. In this way, the effect of shifting Pool peaks on prices can be analysed.

- ➢ The new scenario is shifted by an offset from the original in accordance with a setting on *Offset* drop-down list box. The offset value can be negative. However, the negative values are limited so that no new scenario would contain negative Pool prices.

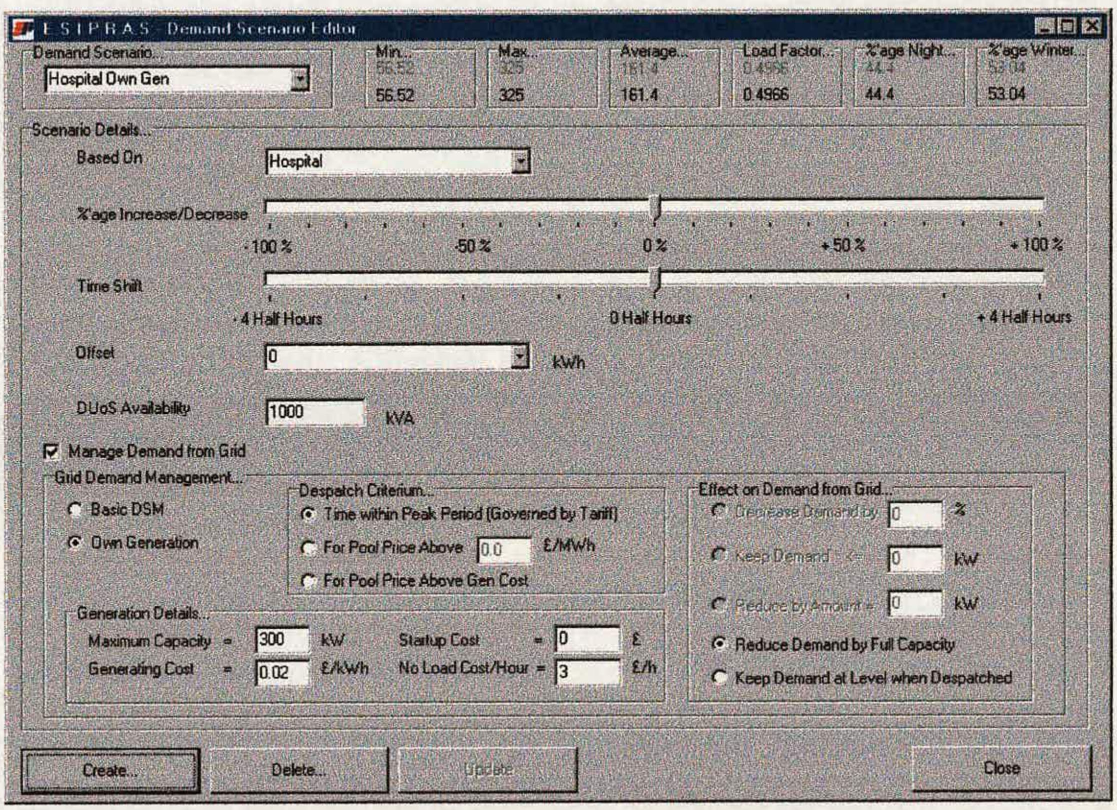
- *Delete* erases the presently selected Pool scenario from memory.

- *Update* re-calculates the selected Pool scenario based on any new the settings.

- *Close* exits the Pool Scenario Editor and returns the user to the *Main Screen.*

In addition, three boxes at the top of the screen provide statistics for the presently selected Pool price scenario.

6.4 The Demand Scenario Editor



Screen Image 6.7 The Demand Scenario Editor

The *Demand Scenario Editor* provides a superset of the facilities offered by the *Pool Scenario Editor*. However:

- The *Spread Factor* is replaced by a *Percentage Change* setting which simply allows the user to create a new scenario where every value is a percentage of the original, either greater or smaller.

In addition, the screen offers three extensions from the *Pool Scenario Editor*:

- *DUoS Availability* provides the user with an edit box in which he can enter a value for the availability capacity of the profile which can then be used to calculate the availability charge within a distribution use-of-system costing.

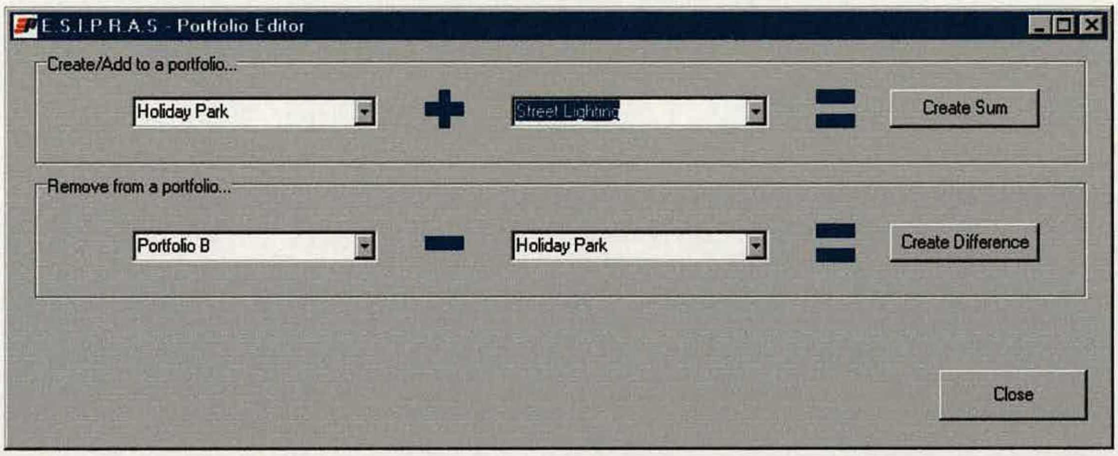
- *Grid Demand Management* attributes that can be applied to a demand scenario. This allows the user to specify either a load management strategy to reduce demand or an on-site electricity generator that the customer or Supplier could switch in. Both methods would reduce the amount of electricity being used from the grid and therefore the amount of electricity bought through the Supplier. In both cases, the user can specify the criterion that needs to be met in order to schedule the reduction in demand or the on-site generation. In the case of Demand Side Management, the user can specify in what way the load is reduced. In the case of on-site generation, the user can enter the specification of the on-site generation These specifications include:

  - *Maximum capacity*
  - *Startup Cost*, portion of capital costs to be associated with this contract
  - *Generating Cost* including fuel,
  - *No Load Cost*, other variable costs including depreciation through use

  In this way, the user of the system can simulate the effect of changes in energy demand of any customer that will employ either of these methods to reduce their load from the grid. Refer to 7.2.6 for an example.

- The statistics shown for each demand scenario incorporate a few more useful values that are specific to demand profiles to aid the analyst.

6.5 The Portfolio Editor



Screen Image 6.8 The Portfolio Editor

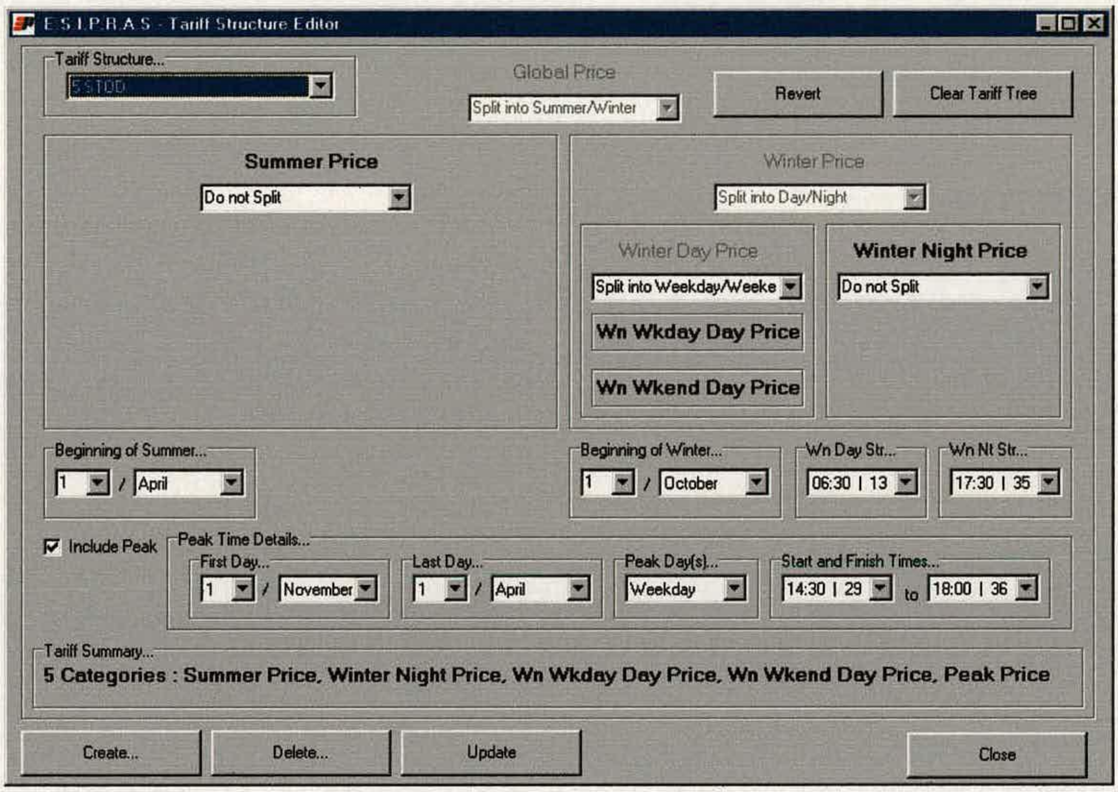
The *Portfolio Editor* allows the user to aggregate demand profiles into one profile or subtract one profile from another by using one of two buttons:

- *Create Sum* creates a new demand scenario which is the sum of the two scenarios selected in the two top list boxes
- *Create Difference* creates a new demand scenario which is the result of subtracting the profile from the scenario in the bottom right list box from the scenario in the bottom left list box.

An analyst might want to create a sum of a set of demand scenarios in order to examine a portfolio's demand profile against set of Pool prices to estimate the net risk of a set of contracts that the portfolio represents. Alternatively, the analyst might want to simply gather together demand data from several customer's sites so that he can calculate a single price for the whole set.

The user may also wish to remove a demand profile that has already been added to a portfolio. Alternatively, the user may wish to remove a risk-free component, e.g. a CfD profile, from a portfolio to examine its remaining risk.

6.6 The Tariff Structure Editor



Screen Image 6.9 Tariff Structure Editor

The *Tariff Structure Editor* presents an editing environment for the user to create, display, edit, delete, and update a large variety of tariff structures. The four buttons at the bottom of the screen, *Create*, *Delete,* and *Update*, behave similarly to those on the *Pool Scenario Editor* and the *Demand Scenario Editor* as described above. In addition:

- *Revert* refreshes the screen to display the details of the presently selected tariff structure in the top left list box.

- *Clear Tariff Tree* collapses the tariff structure to present a price system with a single, global tariff.

The Tariff Structure Editor works using a tree of list boxes. The text in each list box represents the way in which the price is split up from its parent. Initially or when the *Clear Tariff Tree* button is pressed, there is only one global tariff and the text *Global Price* is highlighted at the top of the screen. The list box below it reads "Do not split", which means only one tariff will be used. However, if required, this can be changed to split the price in two, into either:

- a day and night price

- a week and weekend price, or
- a summer and winter price

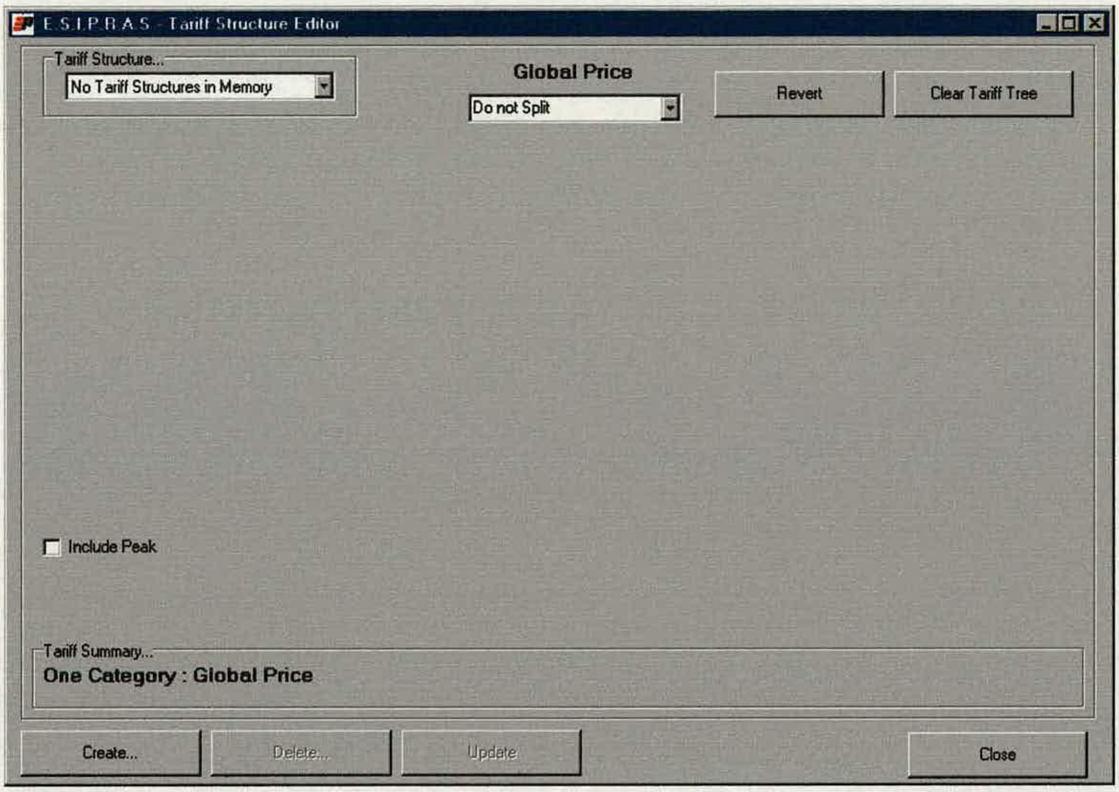
Once split, a few changes occur to the display, as follows.

Firstly, two new list boxes are displayed below the original, now split price. These list boxes at first read "Do not split". The original price text is greyed out and the names of the two new prices appear in bold text to represent the new tariffs. The tariff summary at the bottom of the screen is updated to show the full list of tariffs that now make up the displayed tariff structure. The new tariffs can be split further using either or both list boxes created below the tariff names such that up to eight tariffs can be specified. Depending on what type of splits the user has chosen, further list boxes appear below the tariff tree that may be altered by the user. These include either list boxes to specify the start of daytime and night-time, or the dates that the user wishes to specify the start of summer or winter. These list boxes, which appear when appropriate, begin with the defaults set in the *Date and Time Preferences Dialogue*. For example, if a user selects a day/night split, then the list box displaying the default times for day and night starts appears. The user can then customise these times for the edited tariff structure. The editor allows times to be set for each season, so that if a winter tariff is split into day and night, the system allows the user to specify the beginning of day and night in winter. If a summer tariff is split into day and night, the system offers the user a different pair of list boxes so that the starting times of day and night can be customised for the summer.

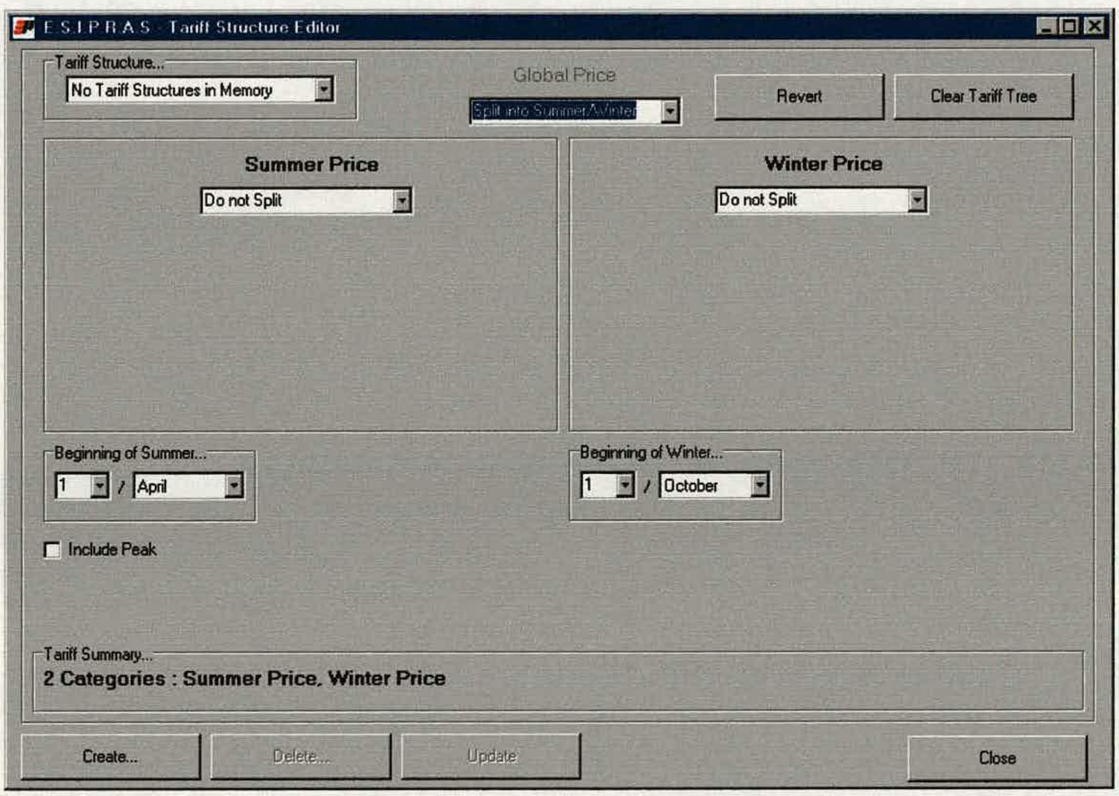
One further option is available. The *Include Peak* tick box is allows the user to add one more tariff to the tariff structure. This tariff specifies a period of time that the Supplier can factor out of the whole price scheme to represent times when demand and Pool price are both likely to be high. It allows the user to specify a period during the day, during either the weekdays or the first four days of the working week, and during only days between two specified dates. This is because high peaks in Pool price and perhaps demand usually only occur during winter on weekday afternoon/early evenings. Again, these list boxes are set initially to the defaults specified in the *Date and Time Preferences Dialogue.*

The series of screen images below, Screen Image 6.10 to Screen Image 6.13, show the steps taken to create a seasonal-time-of-day tariff system with four prices:

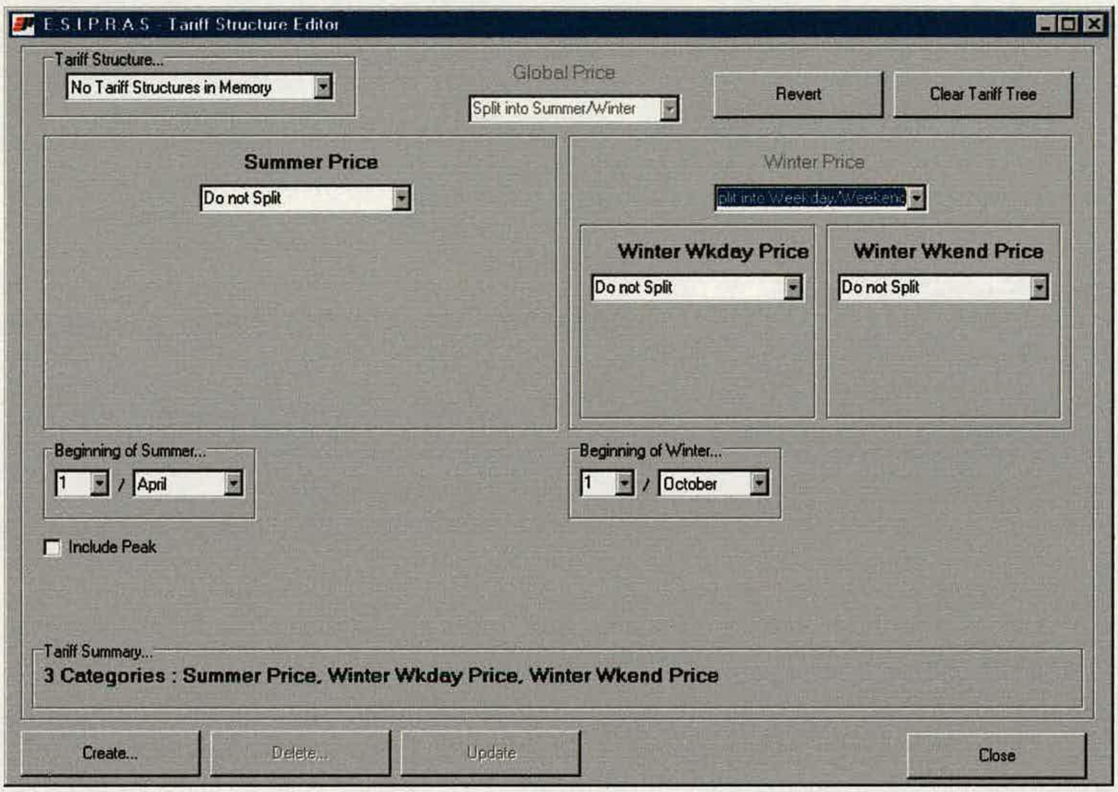
- a summer price
- a winter weekday price
- a winter weekend price
- a peak price



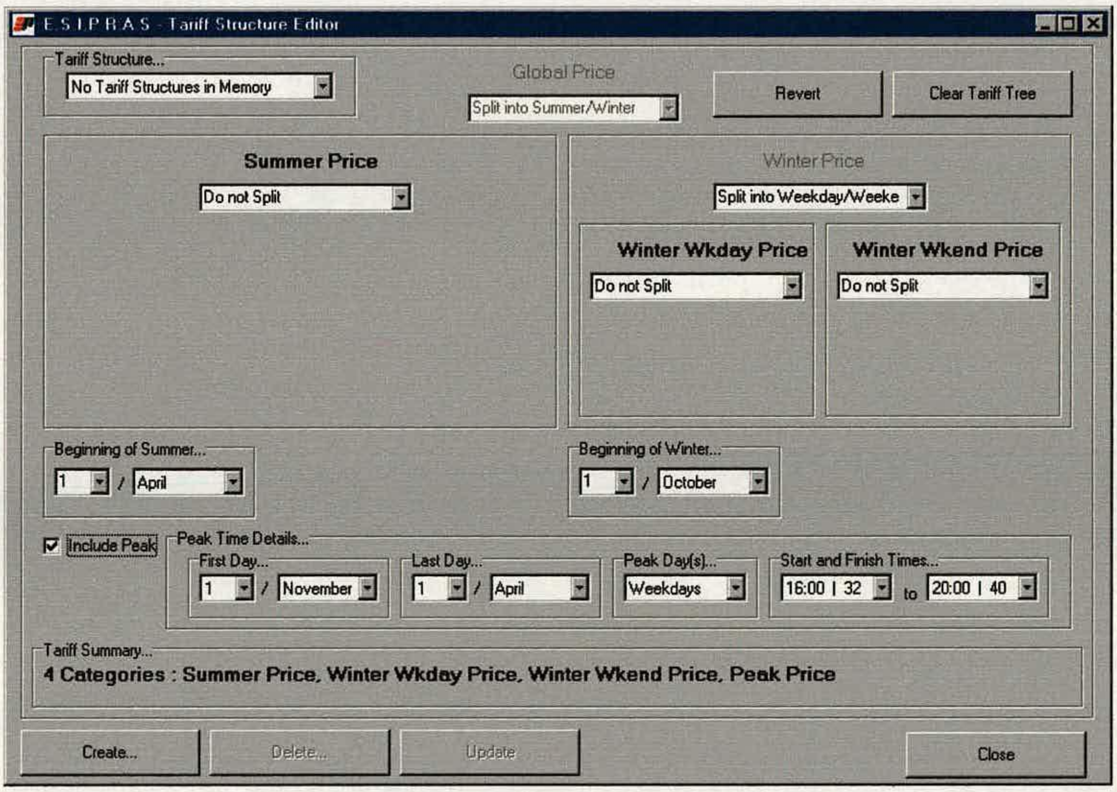
Screen Image 6.10 First Stage in Tariff Specification Example



Screen Image 6.11 Second Stage in Tariff Specification Example

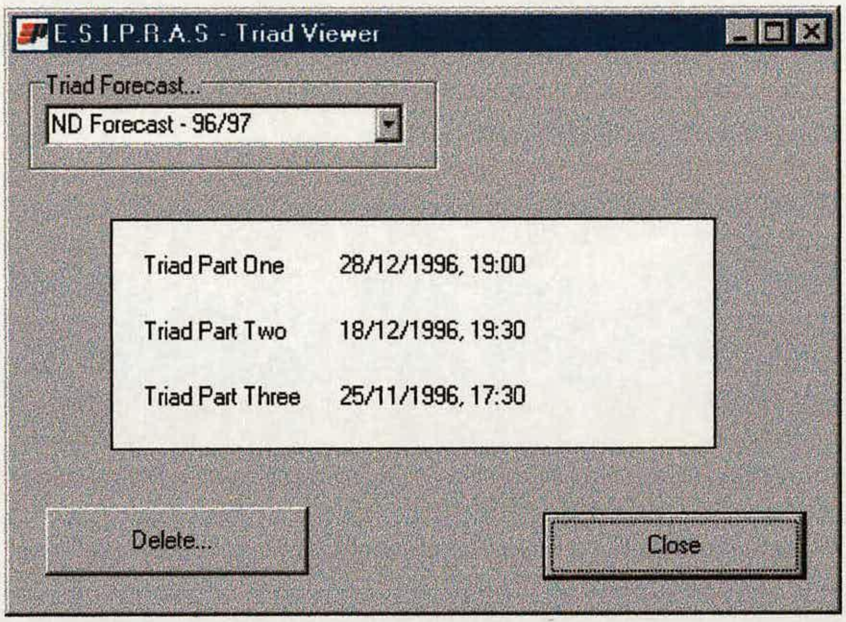


Screen Image 6.12 Third Stage in Tariff Specification Example



Screen Image 6.13 Final Stage in Tariff Specification Example

6.7 The Triad Viewer



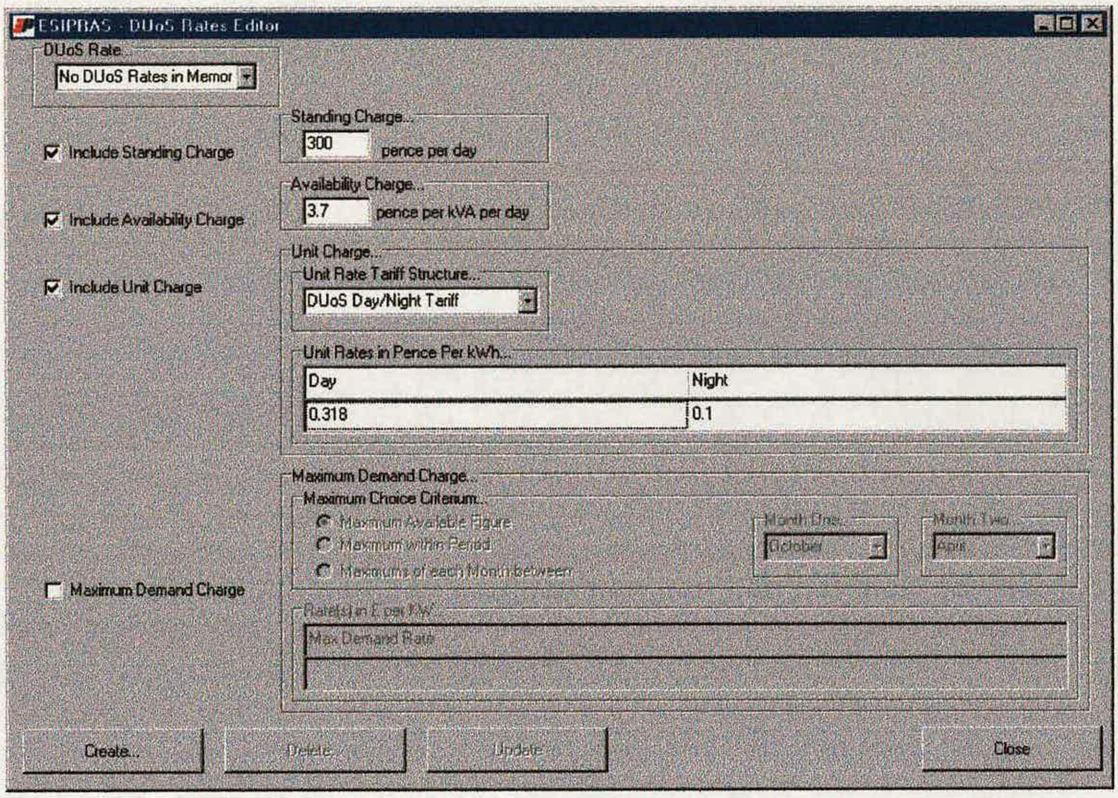
Screen Image 6.14 The Triad Viewer

The *Triad Viewer* provides the user with the means of examining the periods that the *ESIPRAS* has calculated to be the triads within a demand file. These are the three periods during which demand is highest, whilst being each separated by at least ten days. The first of the triad periods is the period of highest demand within a demand profile. The second triad period is the period during which demand is highest within the set of days at least ten days away from the first triad period. The third triad period is the period in which the demand is highest within the set of days at least ten days away from both the first triad period and the second triad period.

The list box at the top left allows the user choose which triad set is displayed.

The *Delete* button allows the user to erase a triad set from memory.

6.8 The DUoS Rates Editor



Screen Image 6.15 The DUoS Rates Editor

The *DUoS Rates Editor* provides the user with a means of creating, editing, deleting and updating a range of distribution use-of-system charges for calculating the contribution of those charges to the overall cost of a customer's contract. The check-boxes allow the user to specify a:

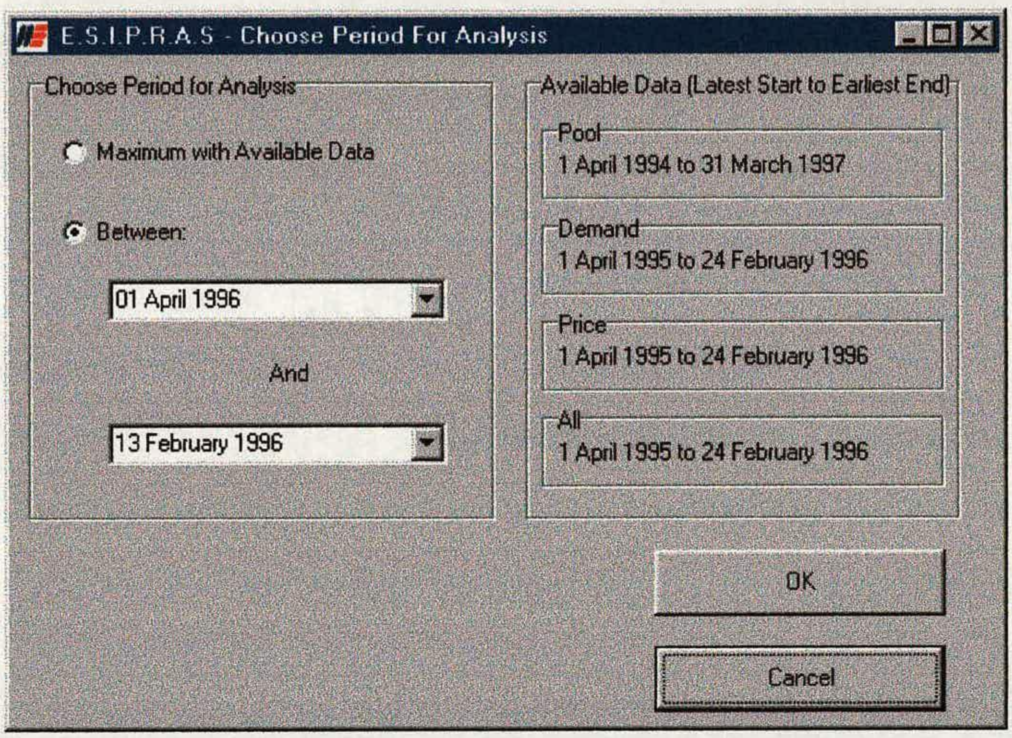
- *Standing Charge*, specified as a fixed price per day of the contract.
- *Availability Charge*, specified as a rate per kVA of capacity per day of the contract. The Availability capacity is part of each demand scenarios attributes and is set on the *Demand Scenario Editor* screen.
- *Unit Price*, specified with a tariff structure from the list of tariff structures in memory and rates for each tariff entered into the grid beneath the name of each tariff component.
- *Maximum Demand Charge*, calculated in one of three ways depending on the radio button selected, using a rate or rates entered into the grid at the foot of the screen:
  - ➤ *Maximum Available Figure* calculates a maximum demand charge as the specified rate multiplied by the highest demand recorded within the demand profile within the analysis period specified, elsewhere, by the analyst.

- *Maximum Within Period* calculates the maximum demand charge as the specified rate multiplied by the highest demand recorded within the period bounded inclusively by the months selected in the two list boxes and within the analysis period specified, elsewhere, by the analyst.

- *Maximum of Each Month Between* calculates the maximum demand charge as the specified rate(s) multiplied by the highest demand recorded within each month within the period bounded inclusively by the months selected in the list boxes.

The buttons at the foot of the screen operate in an analogous way to those of the previous scenario screens described above. For example, once the *Create* button is pressed, the user is prompted to provide a name for the specified DUoS rate system.

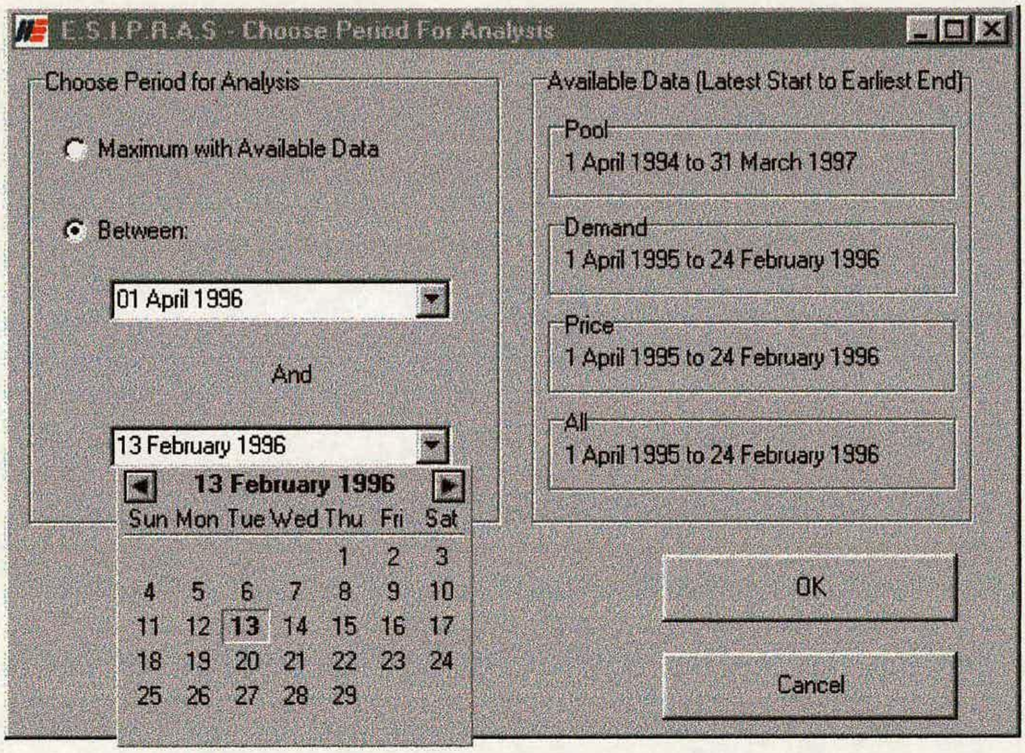
6.9 Analysis Period Dialogue Box



Screen Image 6.16 Analysis Period Dialogue Box

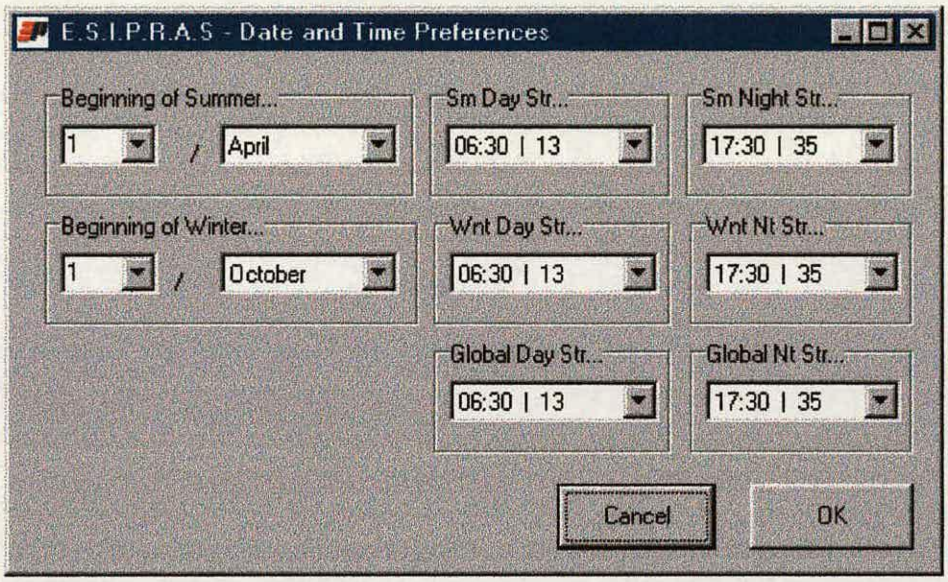
The *Analysis Period Dialogue* box is important as it allows the user to specify the dates between which any analysis should take place. The user may have loaded many large files, but can decide to examine only a particular portion of the data. This screen allows the user to focus on a particular period within the data that has been loaded. It also serves a second purpose; it allows the user, with the help of the system, to identify quickly a period in which there is available data for both Pool price, demand and price information. It prevents the user attempting to price for a longer period than there is available data. No price calculations can take place, or any of the other tools in the *Tools* menu can be used until the Analysis Period has been set. The dialogue box gives the user two options presented with radio buttons:

- *Maximum with Available Data* sets the analysis period to cover the largest common period within all the data that is held in the system.
- *Between* allows the user to select two custom dates. However, the system will not allow the user to select any date without the period for which there is data for any demand, Pool, or price scenario in the system. The custom dates are selected using drop down calendars, one of which is shown in Screen Image 6.17.



Screen Image 6.17 Analysis Period Dialogue Box showing the drop-down calendar

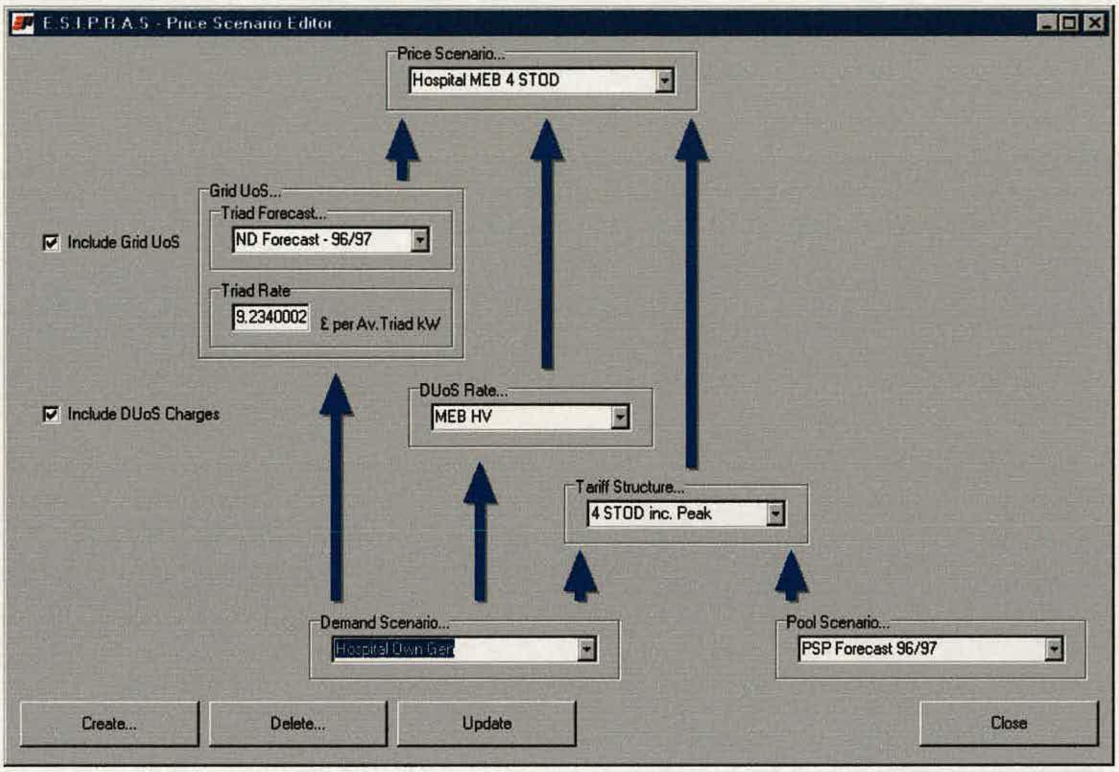
6.10 Date and Time Preferences Dialogue Box



Screen Image 6.18 The Date and Time Preferences Dialogue Box

The *Date and Time Preferences Dialogue* allows the user to set up the default values for a variety of time and date variables used in the rest of the system. Specifically, it allows the user to change the default values which appear in the Tariff Structure Editor and the dates that are used to represent the summer and winter split in the *Data Statistics Screen* (see below).

6.11 Price Scenario Editor

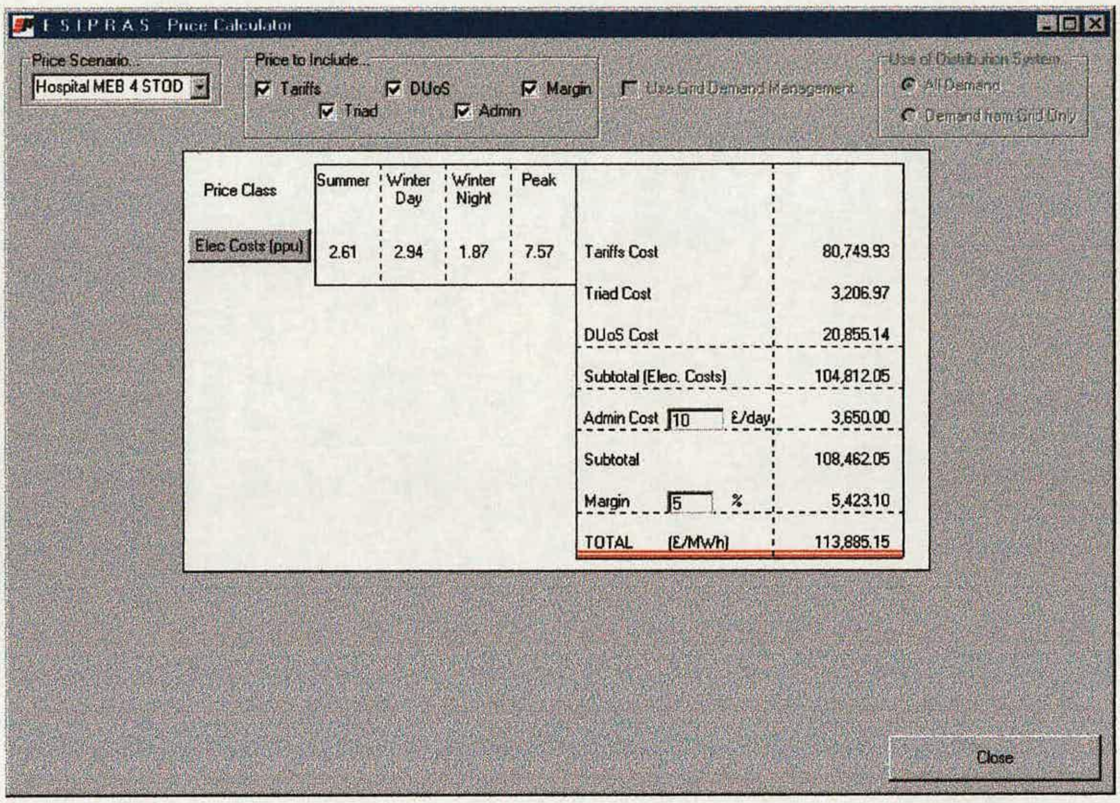


Screen Image 6.19 Price Scenario Editor

The *Price Scenario Editor* is an important screen, where the user can create, display, delete, edit and update price scenarios using a combination of four list boxes. The four buttons behave in a similar fashion as those on the *Pool Scenario Editor*, the *Demand Scenario Editor* and the *Tariff Structure Editor*. The top list box shows the currently selected price scenario. Others allow a price to be created or updated with the selected demand scenario, Pool price scenario and tariff structure. In addition, the user can optionally specify a grid use-of-system rate, its related triad set, and a DUoS charging system.

Once the *Create* button is pressed, the user is asked to provide a name for the Price Scenario. As before, the user is prevented from using a name that is a duplicate of one already in memory. Once this has been completed, the system checks to see if the selected demand scenario specifies a Grid Demand Management strategy. If this is so, *ESIPRAS* processes the demand scenario with the management strategy and then records the result in a new demand scenario. This strategy may depend on Pool price, in which case it uses the data from the Pool scenario specified. This new demand profile is available for inspection in the *Graph* tool and in the *Data Statistics Screen* and is given a name beginning with "From Price - ..." where the dots represent the price scenario name. The tariff or tariffs are then calculated using both the new demand scenario, if a Grid Demand Management strategy was specified, and the original scenario, together with the selected Pool price scenario and the selected tariff structure. The grid use-of-system and DUoS charges are also calculated if selected. The results are recorded in a new price scenario that can be inspected in the *Price Calculator*, the *Price Analyser* and the *Graph* tool.

6.12 The Price Calculator

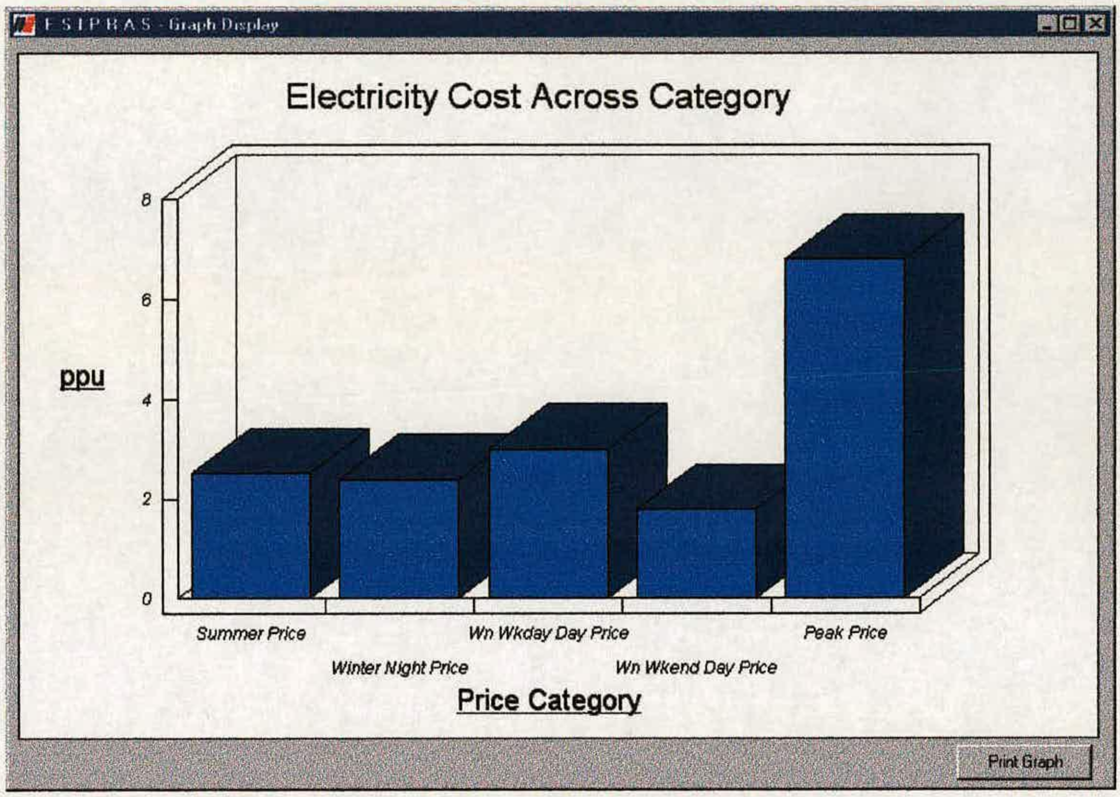


Screen Image 6.20 The Price Calculator

The *Price Calculator* provides the basic means of displaying the tariffs from within a price scenario. This screen will display the details of a price scenario selected in the top left list box. It allows the user to inspect the component costs of the contract to the customer, whilst allowing the user to specify the level of administration costs, quantified in *£/day* of the contract, and the profit margin, specified as an overall percentage. The component costs for the total contract calculation can be selected or deselected with the tick boxes. The components that can be selected include:

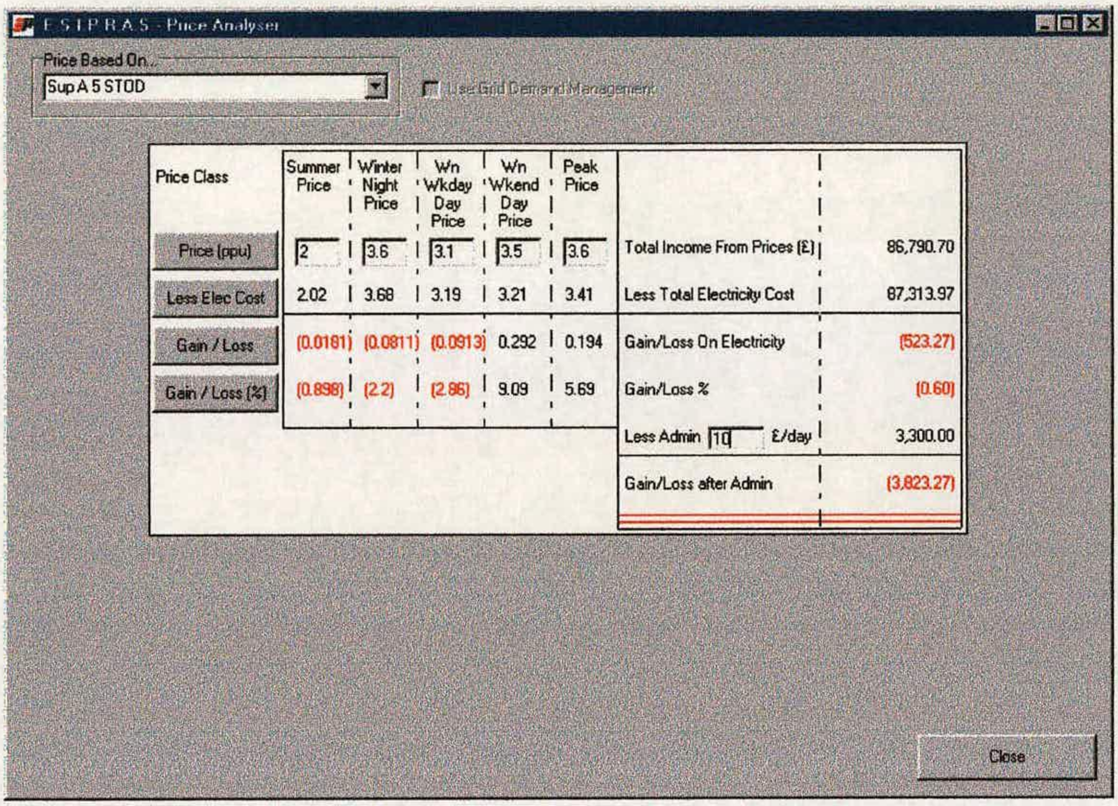
- Electricity costs, or 'Tariffs Cost'
- Grid use-of-system charges, or 'Triad Cost'
- Distribution use-of-system charges, or 'DUoS Cost'
- Administration charges, or 'Admin'
- Margin

Administration costs are assumed to cover all costs associated with the contract except for the electricity tariffs and the use-of-system charges. The button marked "Elec costs (ppu)" presents a bar graph of the tariffs, an example of which is shown below in Screen Image 6.21, so that the user can more easily compare the prices.



Screen Image 6.21 Example graph of 'ppu' values

6.13 The Price Analyser

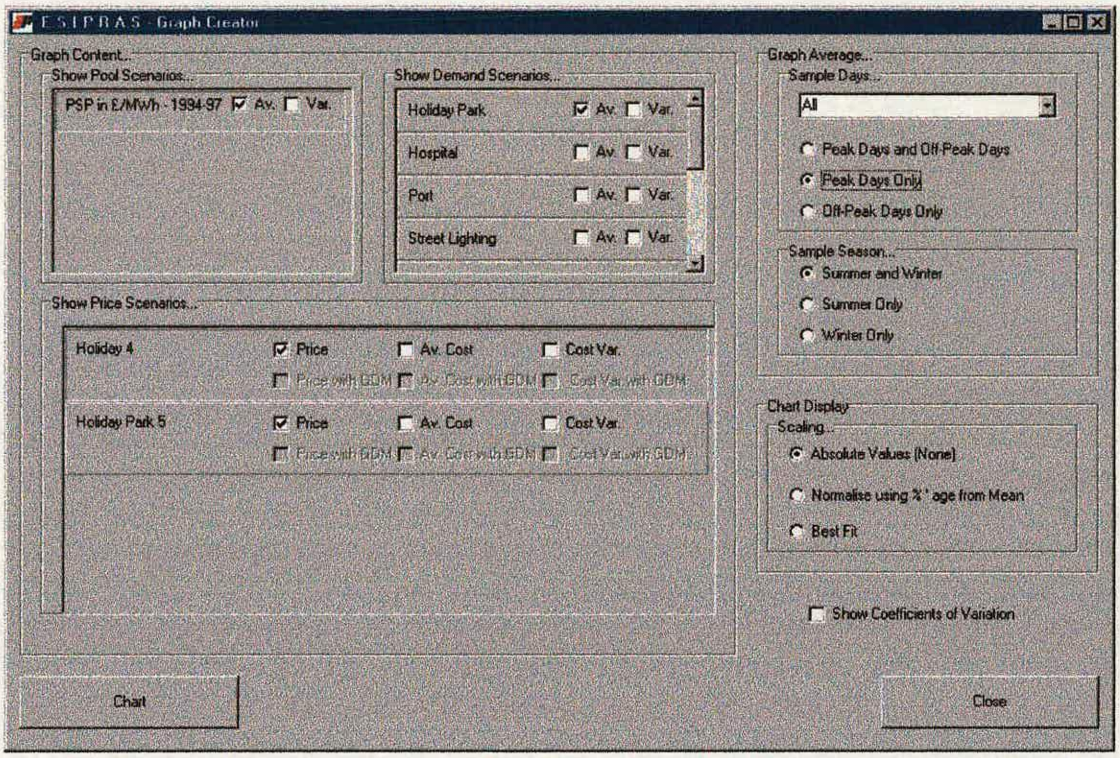


Screen Image 6.22 The Price Analyser

The *Price Analyser* is similar to the *Price Calculator*, but is intended to provide the user with a slightly different tool. The *Price Analyser* allows the user to compare a set of tariffs typed into an array of edit boxes with tariffs from a selected price scenario. Since the tariffs in the price scenarios are calculated on the basis of meeting electricity cost, they can be considered as representing break-even energy cost prices, the prices at which the contract would not make or lose anything. Thus, the *Price Analyser* allows the user to check the level of profit or loss from a given set of tariffs in the edit boxes. This would be particularly useful where the user wishes to compare quickly a quote from a competitor. The user might also like to judge, based on a range of different scenarios for demand and Pool price, whether the contract, based on a fixed set of tariffs, is likely to make a profit, break-even, or return an acceptable loss. See the example in the next chapter.

The buttons labelled with the price classes can be pressed to obtain bar graphs of value versus price category for each of the initial stages of the calculation.

6.14 The Graphing Screens



Screen Image 6.23 The Graph Creator Screen

Graph is a flexible graphing tool that provides a set of facilities designed specially for the purpose of electricity contract analysis. It allows the analyst to visualise the data he is manipulating in order that he may identify interesting features. For example, the analyst may wish to inspect where peaks of demand usually occur in a demand scenario, and how they relate to the peaks in a Pool price scenario. When the user selects the *Graph* tool in the *Tool* menu, he is first presented with the *Graph Creator* screen, one that asks the user to specify the exact content of a graph, a step that must first be completed before the graph is displayed.

All graphs depict 48 half-hour values for each series selected and as such can either represent the average day from a sample of days and/or the amount of spread of each selected scenarios' data in each half-hour from a sample of days.

Three panel list boxes provide a means to select each of the scenarios that the user wishes to be presented on the same graph. The panel list boxes each contain a list of all the scenarios in each of the three categories of Pool price, demand and price. Each item in the list boxes provides two or more tick boxes. The user can tick a scenario if he wishes to include that scenario in the graph, and at the same time specify whether he wishes to inspect a series of average values and/or a series containing a measure of spread of the values from that scenario. The spread measure can be specified as either variance or the coefficient of variation using the tick box on the bottom right of the screen. The averages and measures of spread are calculated from the set of days that meet user specified criteria within the analysis period. For example, the user can choose to display a graph of the average weekend day, containing information from any of the available scenarios. The system creates a graph with values for each half-hour of the day calculated from each selected scenario's curve from all the days within the analysis period that meet the chosen criteria. The user can specify the day selection criteria using the top two group boxes in the centre of the screen, *Sample Day* and *Sample Season*:

- The *Sample Day* group box contains a list box and a set of radio buttons. The list box allows the type of day to be chosen, e.g. weekday, Thursday, etc. The radio buttons are active only if one or more price scenarios with a peak tariff have been selected. Depending on which one is selected, the user can specify whether the sample set of days should include days with peak periods in them, days without peak periods within them, or either.

- The *Sample Season* group box just contains a set of three radio boxes, *Summer and Winter*, *Summer Only*, and *Winter Only*. These allow the user to select whether the sample days should include summer days, winter days, or both. The definition of the start of these seasons is taken to mean those set in *the Date and Time Preferences Dialogue*. These radio boxes are each greyed out depending on what period the user has chosen the Analysis Period to be. For example, if the analysis period just covers summer days, then the *Winter Only* radio will not be available.

In the case of price scenarios there are six tick boxes provided below the price scenario list box that allow the user to specify which information from a price scenario should be shown:

- *Av. Cost*, when ticked, commands the system to include the average electricity cost curve from the set of days that meet the day selection criteria. The average electricity cost curve is simply a curve representing the average cost of electricity for each half-hour that is the result of multiplying the Pool price curve by the demand curve.

- *Cost Var.*, when ticked, commands the system to include a curve of the spread of each half-hour's cost values, calculated as above, from the set of days that meet the day selection criteria. The spread measure used is either variance of coefficient of variation, depending on whether the *Show Coefficients of Variation* tick box is selected.

- *Price*, when ticked, commands the system to show the average of the tariffs for each selected price scenario for each half-hour of the day from the set of days that meet the day selection criteria.

The remaining three tick boxes, if enabled, allow the user to graph the above information for price scenarios with their Grid Demand Management strategies activated. These tick boxes are not enabled if the price contains no Grid Demand Management information.

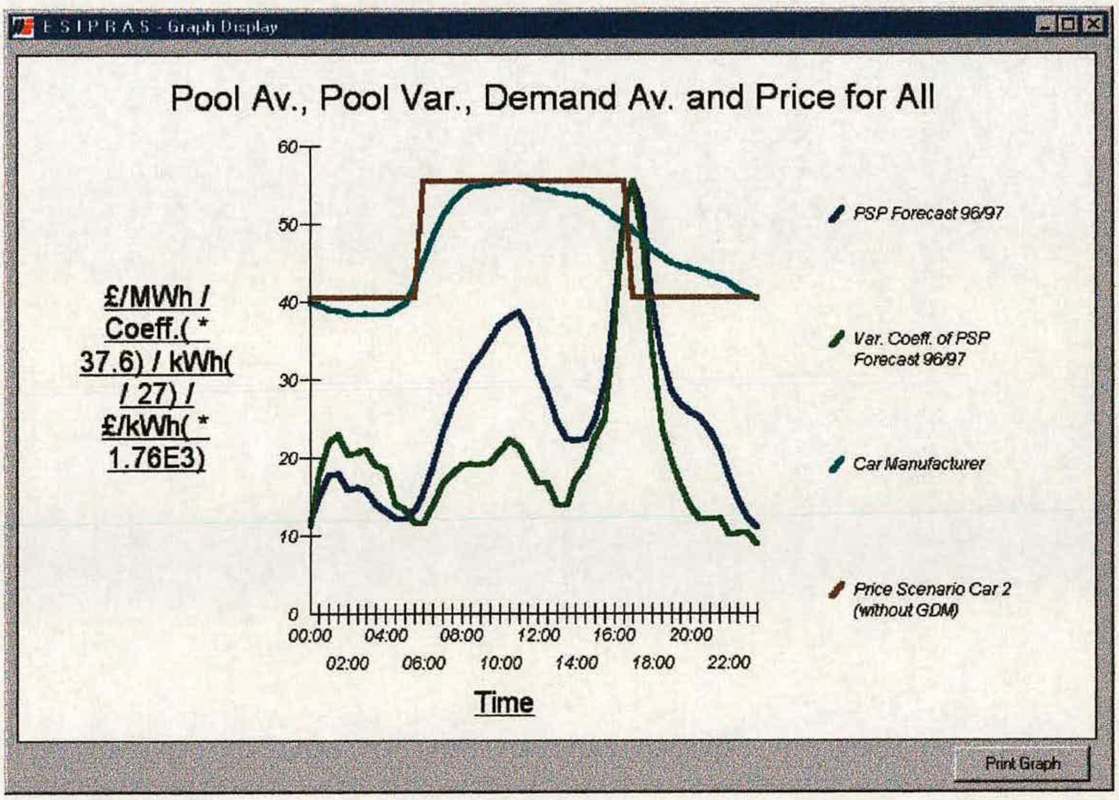
Finally the last group box at the bottom centre of the screen allows the user to specify the scaling strategy for each of the curves in the graph:

- *Absolute Values* does not scale any of the curves. The greatest value on the graph's *y*-axis becomes the greatest value from the series chosen to be displayed.

- *Normalise using %'age from Mean* causes the series' curves to be represented as percentage deviations from their means.

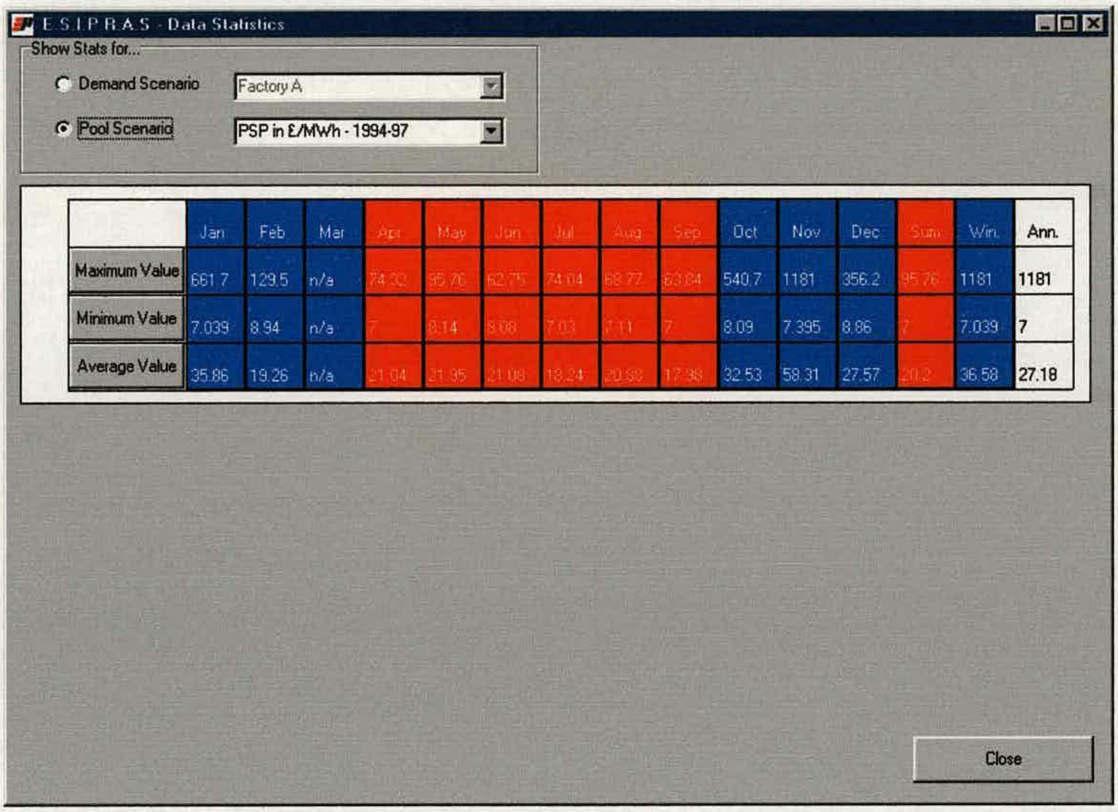
- *Best Fit* scales each of the series so that the maximum values for each of the series match. The scaling factors are displayed on the *y*-axis label.

The *Chart* button is greyed out if no series are specified. Once at least one scenario has been chosen to be presented on the graph, the button becomes active. The user may then click the button to create a graph of a day with the chosen information. When this occurs, the system calculates the curves for the graph, and then displays the graph on the *Graph Display* screen. The display includes a title reflecting the contents of the graph, labelled axis, a legend showing which curves refer to which coloured curves and the curves for the selected scenarios themselves.



Screen Image 6.24 Graph Screen

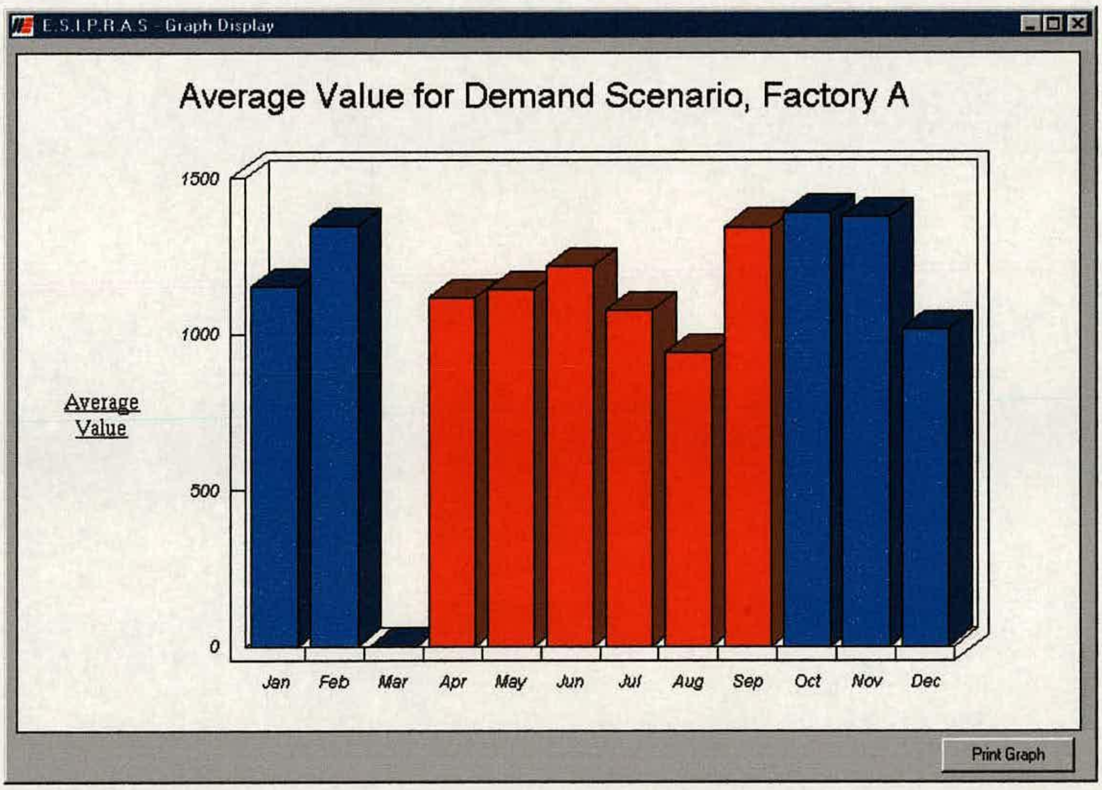
6.15 The Data Statistics Screen



Screen Image 6.25 The Data Statistics Screen Showing Statistics for a Pool Scenario

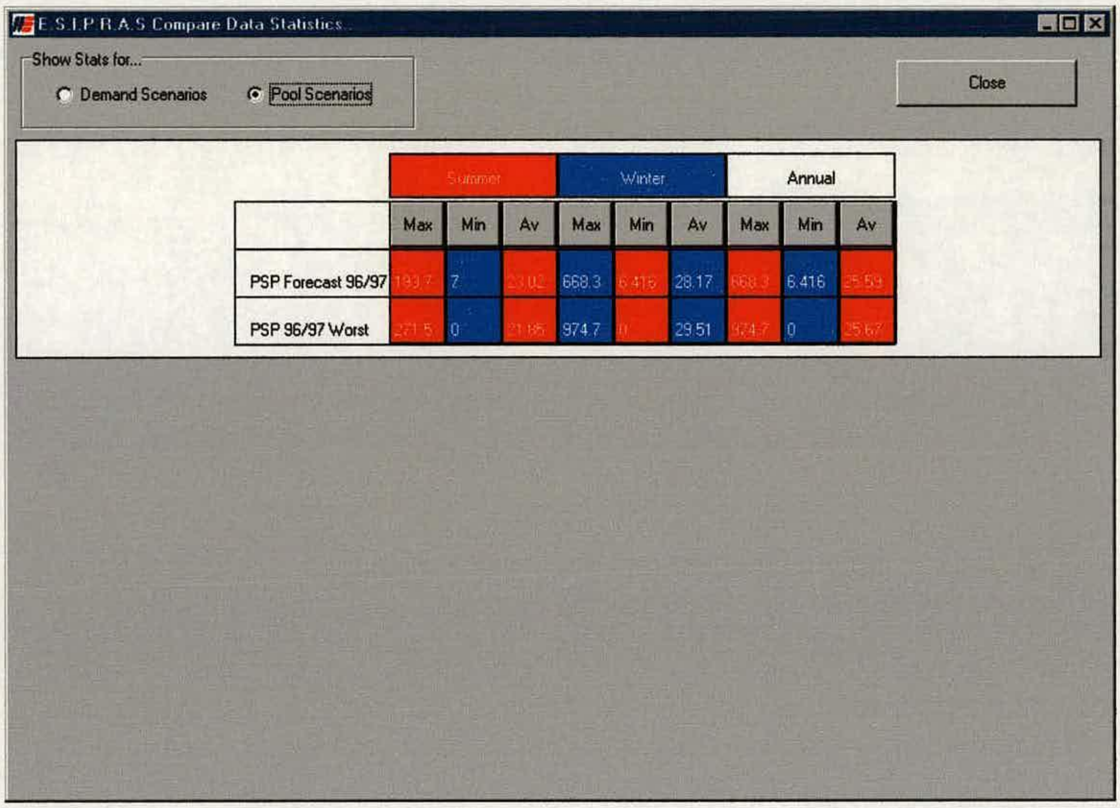
The Data Statistics Screen allows the user to inspect important statistical information for each of the pool scenarios and the demand scenarios held in memory. The screen provides a specific set of statistics for each scenario type and each set is shown in a different table. Examples of both types of table are shown in Screen Image 6.25 and Screen Image 6.26. The radio boxes and drop-down lists in the group box at the top left are used to select the scenario for inspection. The radio boxes select the scenario type and the drop-down list the actual scenario. The statistical tables presented on this screen are colour coded. Winter and winter month values are presented on a blue background, whereas summer and summer month values are presented on a red background. The buttons down the left-hand side of the table create a graph of the chosen statistic and its distribution across the year. When the user clicks one of these buttons, the system generates a bar graph displayed in the *Graph Display* screen that is invoked. An example of one such graph is shown in Screen Image 6.27.

Screen Image 6.26 The Data Statistics Screen Showing Statistics for a Demand Scenario



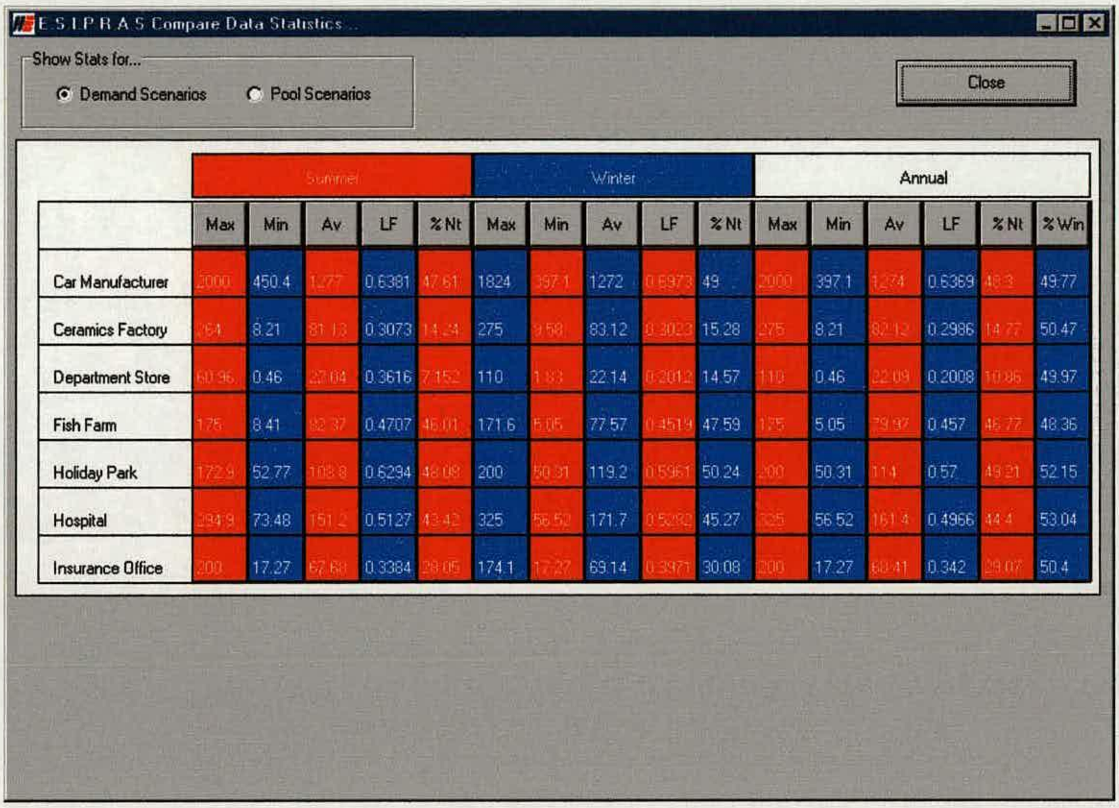
Screen Image 6.27 Graph Display Screen showing a Bar Graph of Average Values Across the Year for a Demand Scenario

6.16 The Compare Data Statistics Screen



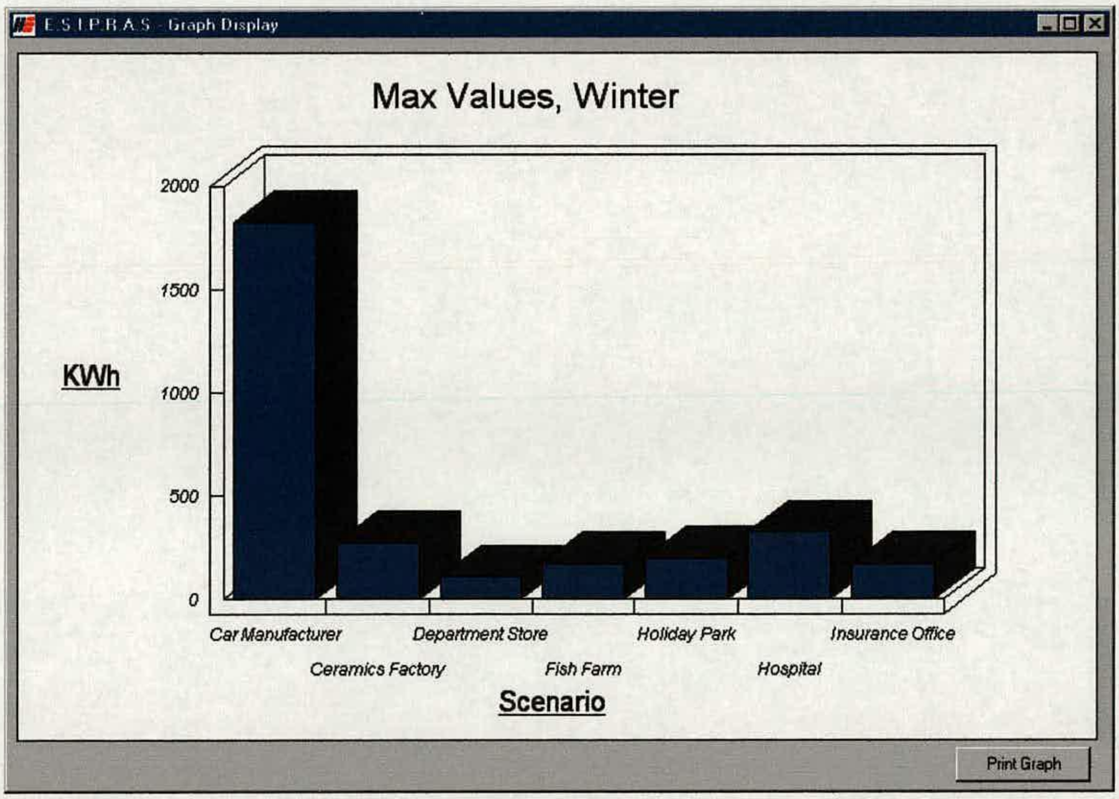
Screen Image 6.28 The Compare Statistics Screen showing two Pool scenarios

The *Compare Statistics Screen* provides a similar facility to the *Data Statistics Screen*, but foregoes some of the latter's detail to include all the available scenarios from one class in one table, so that the analyst can more easily compare key statistics from each scenario. The radio boxes allow the user to select either the set of demand scenarios or the Pool scenarios in memory. Screen Image 6.28 shows an example of the screen detailing the two Pool prices in memory. Alternatively, Screen Image 6.29 shows an example of the screen detailing a number of demand scenarios in memory. The analyst can press any of the available buttons to see a graph of each statistic across the detailed scenarios. Screen Image 6.30 shows the graph screen that appears after the user has pressed the 'Max' button in the winter portion of the table in Screen Image 6.29.



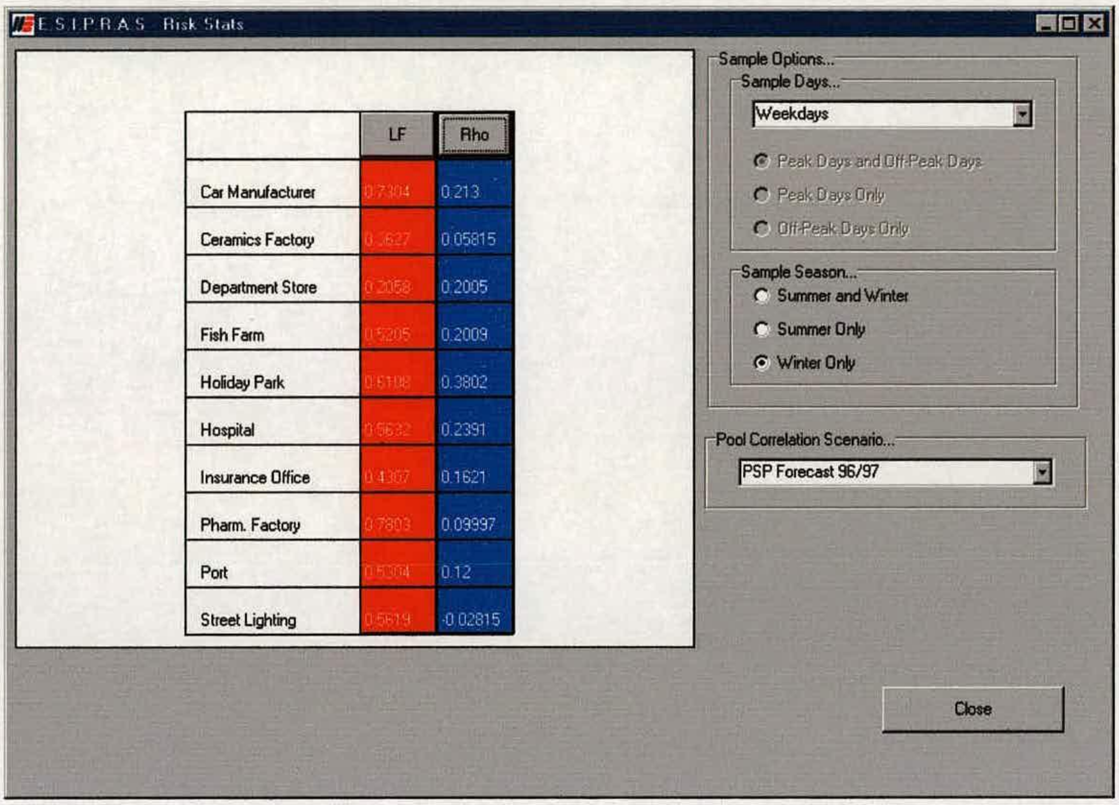
	Summer					Winter					Annual					
	Max	Min	Av	LF	%Nt	Max	Min	Av	LF	%Nt	Max	Min	Av	LF	%Nt	%Win
Car Manufacturer	2000	450.4	1277	0.6381	47.61	1824	397.1	1272	0.6973	49	2000	397.1	1274	0.6369	48.3	49.77
Ceramics Factory	264	8.21	81.13	0.3073	14.24	275	9.58	83.12	0.3023	15.28	275	8.21	82.12	0.2986	14.77	50.47
Department Store	60.96	0.46	22.04	0.3616	7.152	110	1.83	22.14	0.2012	14.57	110	0.46	22.09	0.2008	10.86	49.97
Fish Farm	175	8.41	82.37	0.4707	46.01	171.6	5.05	77.57	0.4519	47.59	175	5.05	79.97	0.457	46.77	48.36
Holiday Park	172.9	52.77	108.8	0.6294	48.08	200	50.31	119.2	0.5961	50.24	200	50.31	114	0.57	49.21	52.15
Hospital	294.9	73.48	151.2	0.5127	43.42	325	56.52	171.7	0.5282	45.27	325	56.52	161.4	0.4966	44.4	53.04
Insurance Office	200	17.27	67.68	0.3384	28.05	174.1	17.27	69.14	0.3971	30.08	200	17.27	68.41	0.342	29.07	50.4

Screen Image 6.29 The Compare Statistics Screen showing a list of the demand scenarios in memory



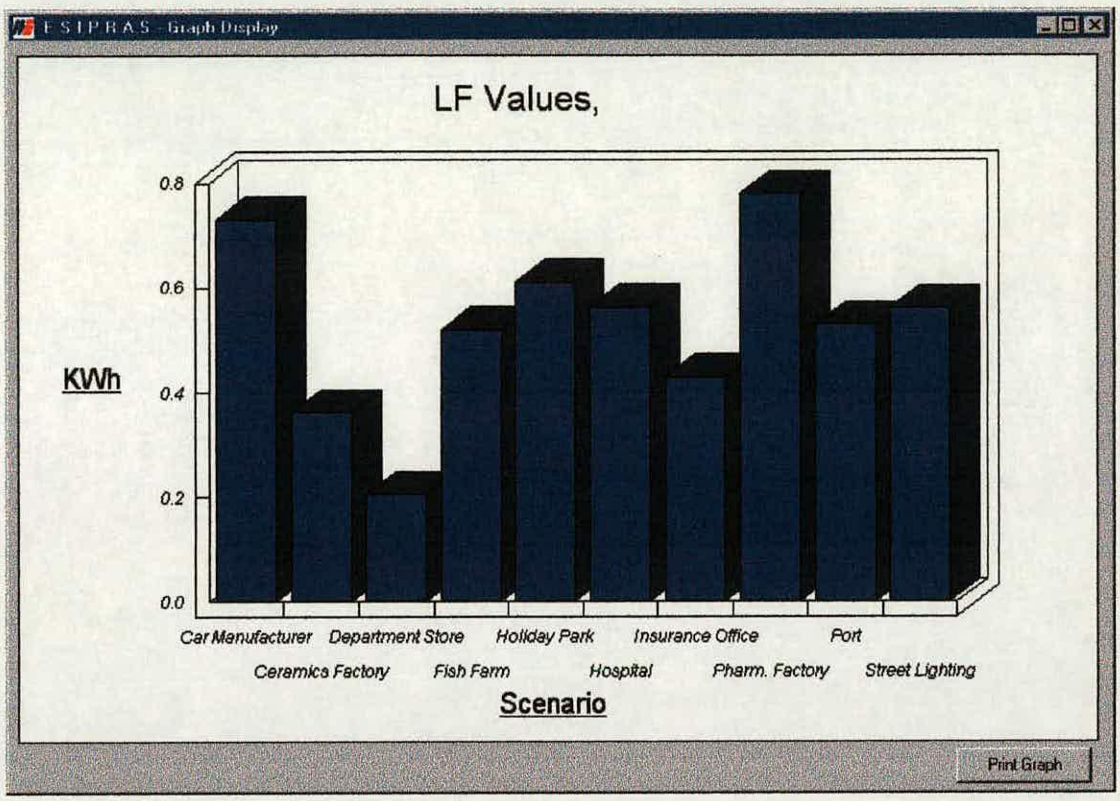
Screen Image 6.30 Example graph generated from the Compare Statistics Screen

6.17 The Risk Statistics Screen



Screen Image 6.31 The Risk Statistics Screen

The *Risk Statistics Screen* provides the user with a table comparing two risk coefficients across all the demand scenarios in memory. The risk coefficients provide an alternative method of measuring the potential sensitivities of contracts to movements in Pool prices and consumption patterns to the more laborious approach of creating different scenarios and calculating each set of prices. The coefficients are *Load Factor* and *Rho*. *Rho* is calculated as the coefficient of correlation of each demand scenario with the Pool scenario indicated in the list box. The sample set of days from which these measures are calculated can be selected using the Sample Options criteria in a similar way as on the *Graph Creator Screen*. For example, the user can inspect the values of these measures for just winter weekdays, as in Screen Image 6.31. Graphs of the values can be created by pressing one of the buttons at the top of the table, e.g. Screen Image 6.32. Load Factor is discussed in a previous chapter, in 4.6.2.2.2, and the design notes, in 8.7.1. For a discussion of *Rho*, see the latter.



Screen Image 6.32 A graph created from the Risk Statistics Screen

Chapter 7 Example Analyses

7.1 *Introduction*

This chapter provides basic examples of how the software might be used.

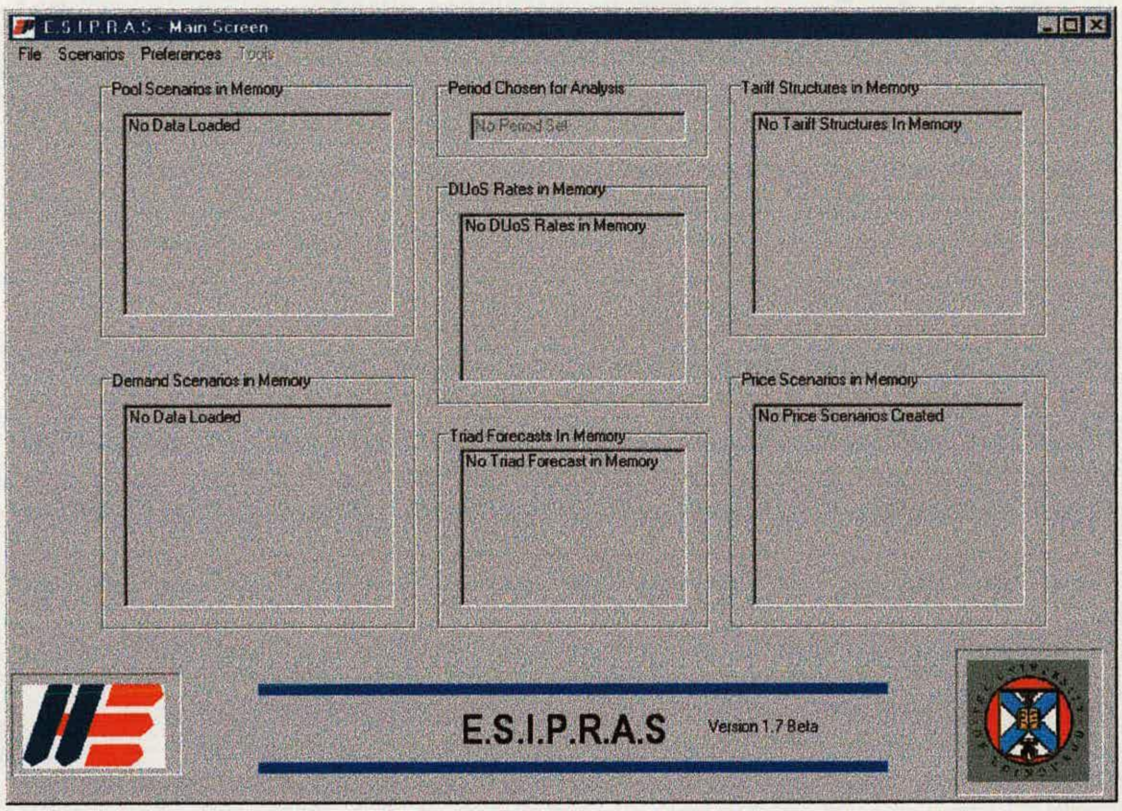
7.2 *Example Price Analyses*

7.2.1 A Basic Contract Pricing

In this example, the analyst wishes to cost a Supply contract for a hospital that is in the Midlands Electricity Board region for the period April 1st 1996 to March 31st 1997. For the purpose of this example, the date is assumed to be sometime before April 1st 1996. The analyst has already prepared a forecast of the hospital's expected demand and has acquired a forecast of Pool price and a national demand forecast from another department.

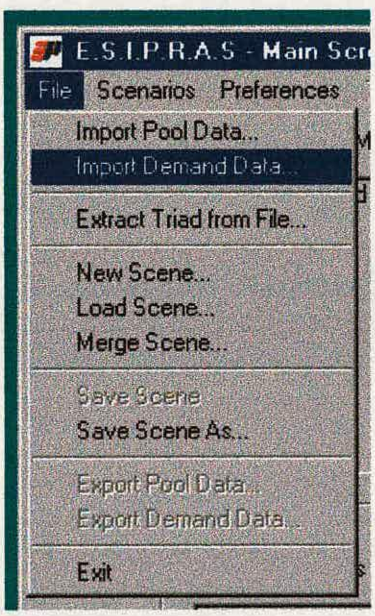
Screen Image 7.1 The analyst can execute *ESIPRAS* from the icon within this window

The analyst begins by starting *ESIPRAS* from its icon on the desktop of his *Windows* machine, see Screen Image 7.1. He is then presented with the blank *Main Screen* as shown in Screen Image 7.2

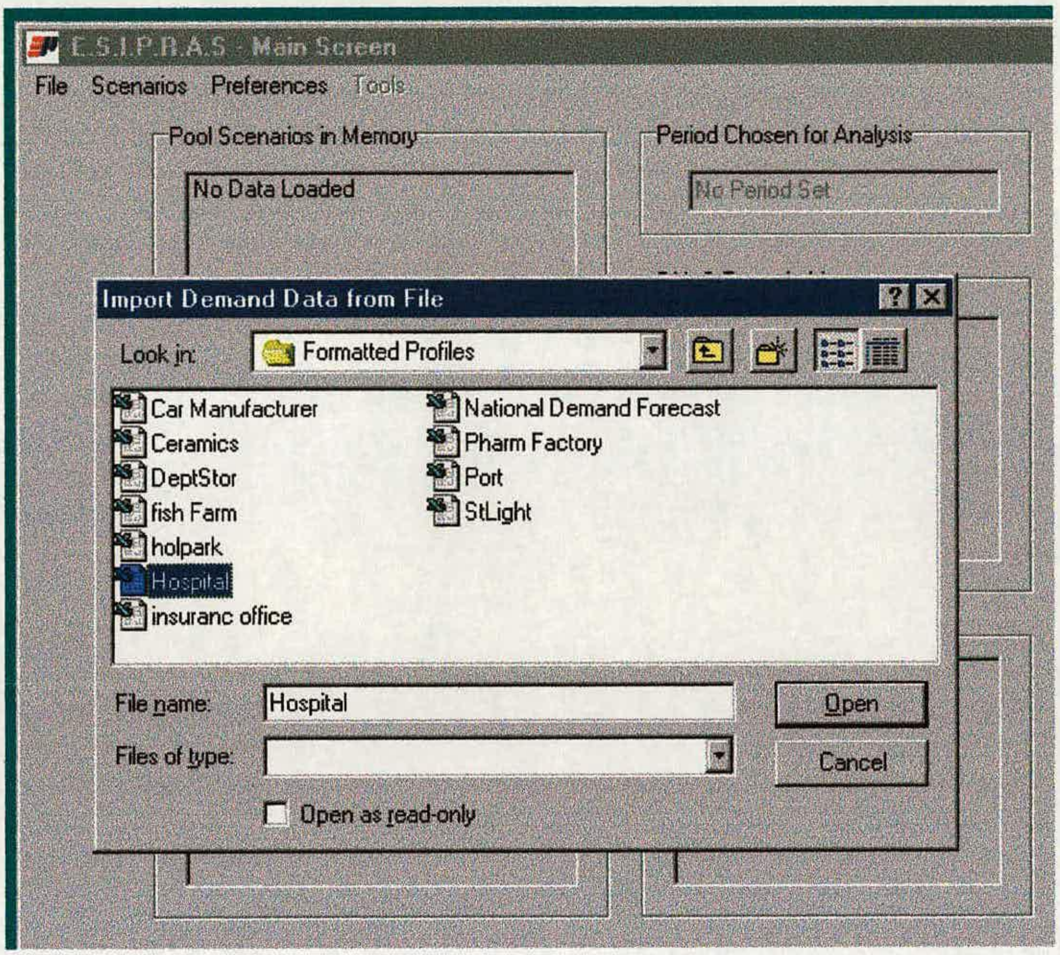


Screen Image 7.2 *ESIPRAS* at start-up

The analyst's first step is to import his demand forecast by selecting the relevant command in the File menu as shown in Screen Image 7.3. This presents the analyst with a standard 'Open' dialog (Screen Image 7.4), from which he selects the spreadsheet file containing the demand forecast, 'Hospital'.

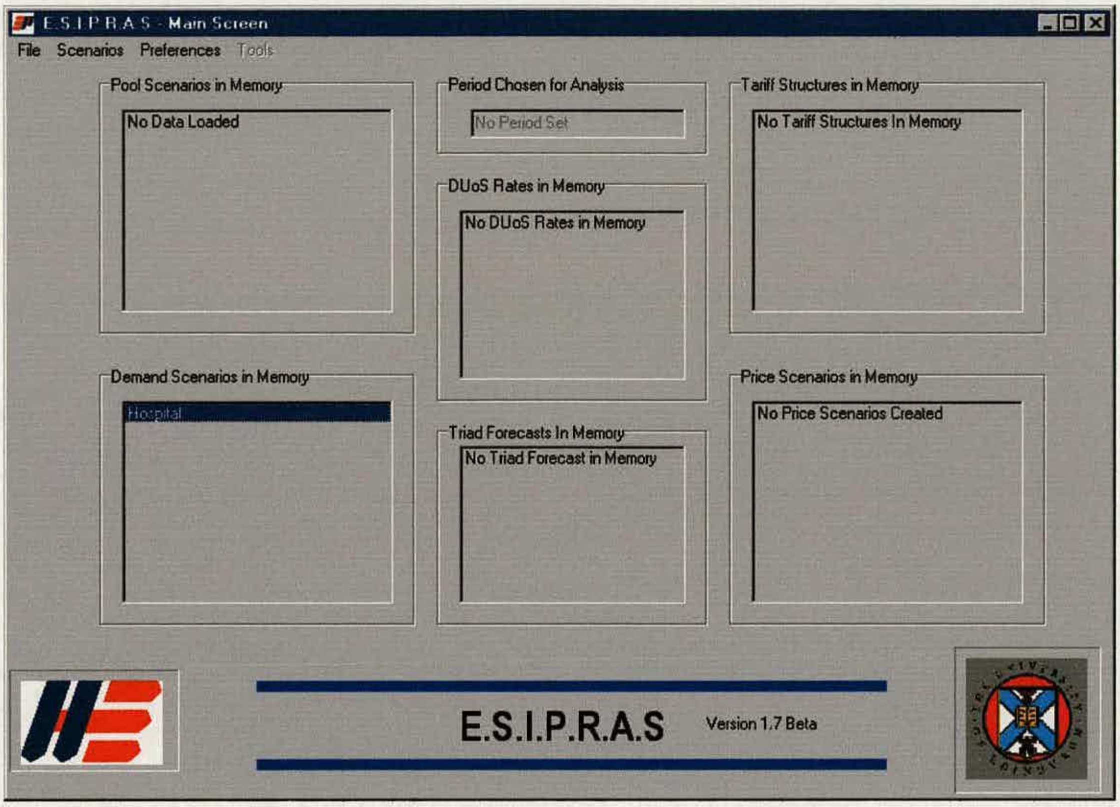


Screen Image 7.3 Using the *File* menu to import a demand file from spreadsheet



Screen Image 7.4 Selecting the demand profile within the 'Open' dialogue

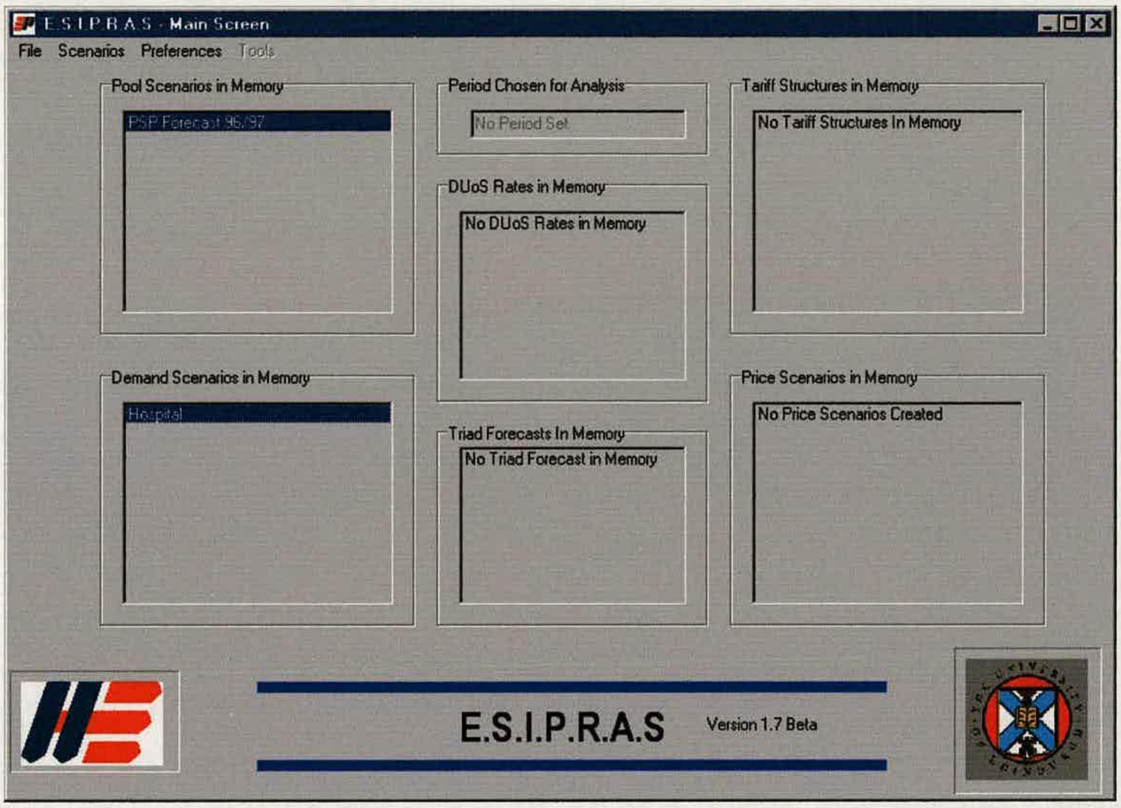
Once the file has been imported, the analyst returns to the Main screen, see Screen Image 7.5.



Screen Image 7.5 The *Main* screen after having imported a demand profile

The next step for the analyst is to import the Pool forecast, achieved by selecting the relevant item on the File menu, see Screen Image 7.6, and opening the relevant file from an 'Open' dialogue box as before.

Screen Image 7.6 Using the *File* menu to import Pool price data from a spreadsheet file

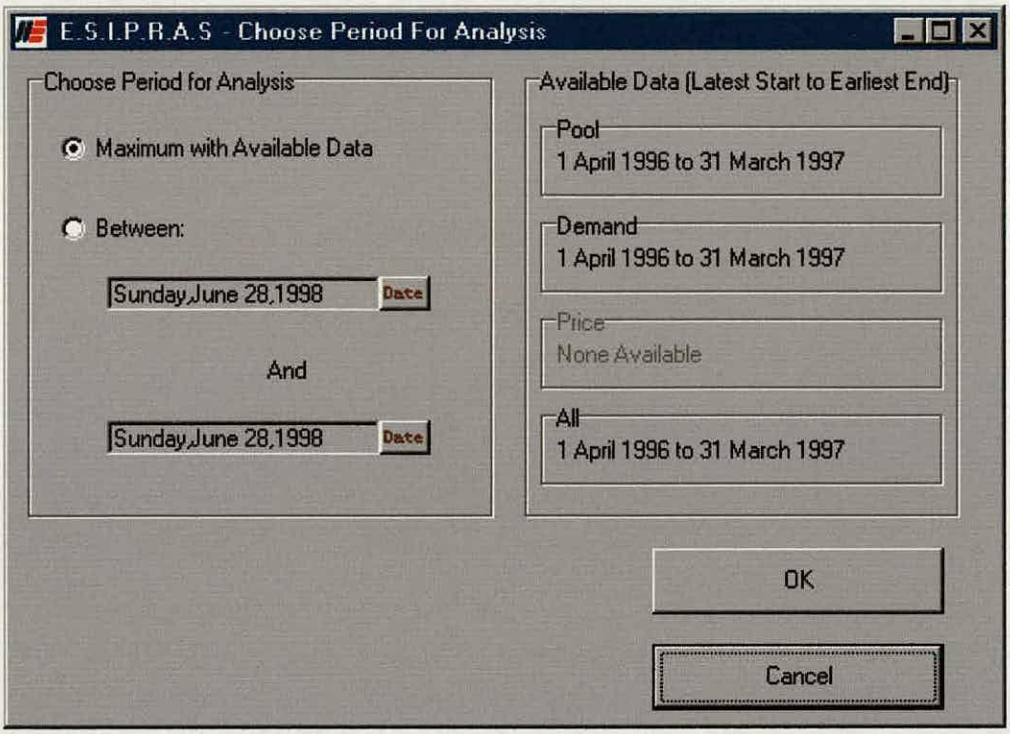


Screen Image 7.7 The *Main* screen after subsequently having imported the Pool forecast

The Main screen then reflects the presence of the imported Pool file, see Screen Image 7.7. The next step is to set the analysis period, the dates between which the user wishes to cost the contract. The analyst selects the relevant item in the Preferences menu, see Screen Image 7.8.

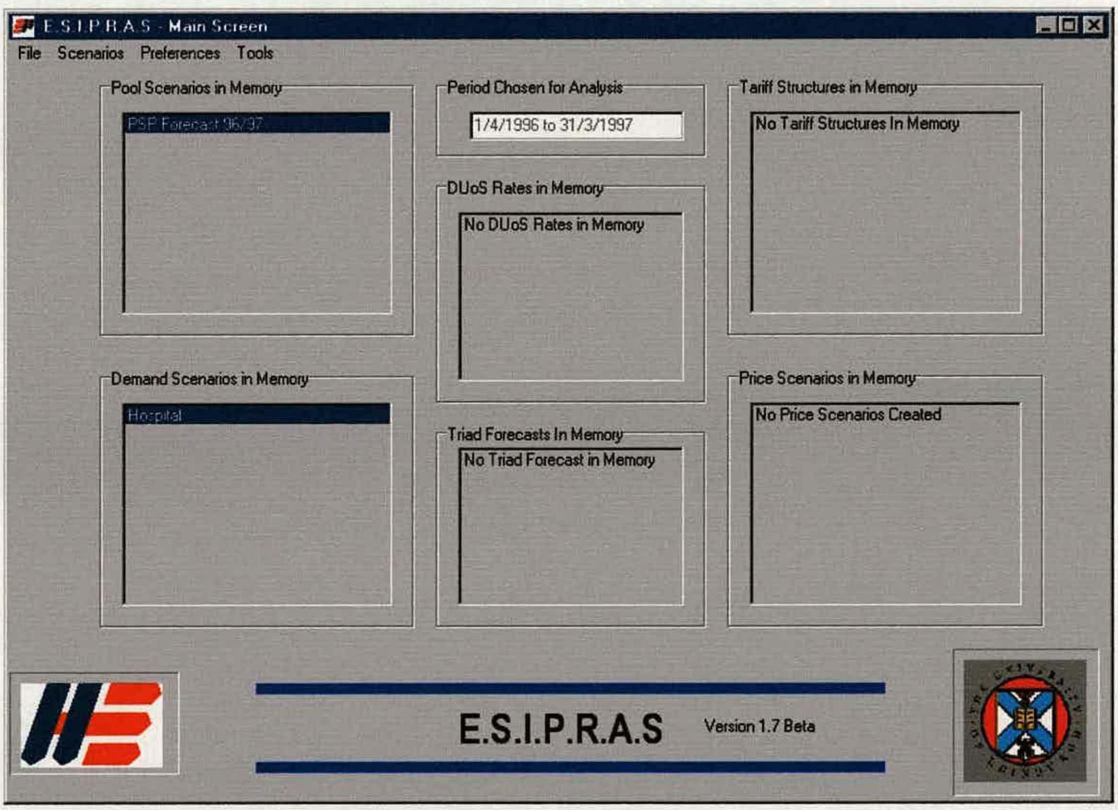
Screen Image 7.8 Using the *Preferences* menu to initialise the analysis period

This brings up the Choose Period dialogue box. The analyst selects the 'Maximum with Available Data' radio and presses the 'OK' button, see Screen Image 7.9. The demand profile contains only the period for which the analyst wishes to cost, so there is no need for him to specify a subset of the available data, an option that is available on this screen.



Screen Image 7.9 Selecting the maximum available analysis period on the *Choose Period* dialogue box

The *Main* screen is updated by the system to display the chosen analysis period, see Screen Image 7.10.

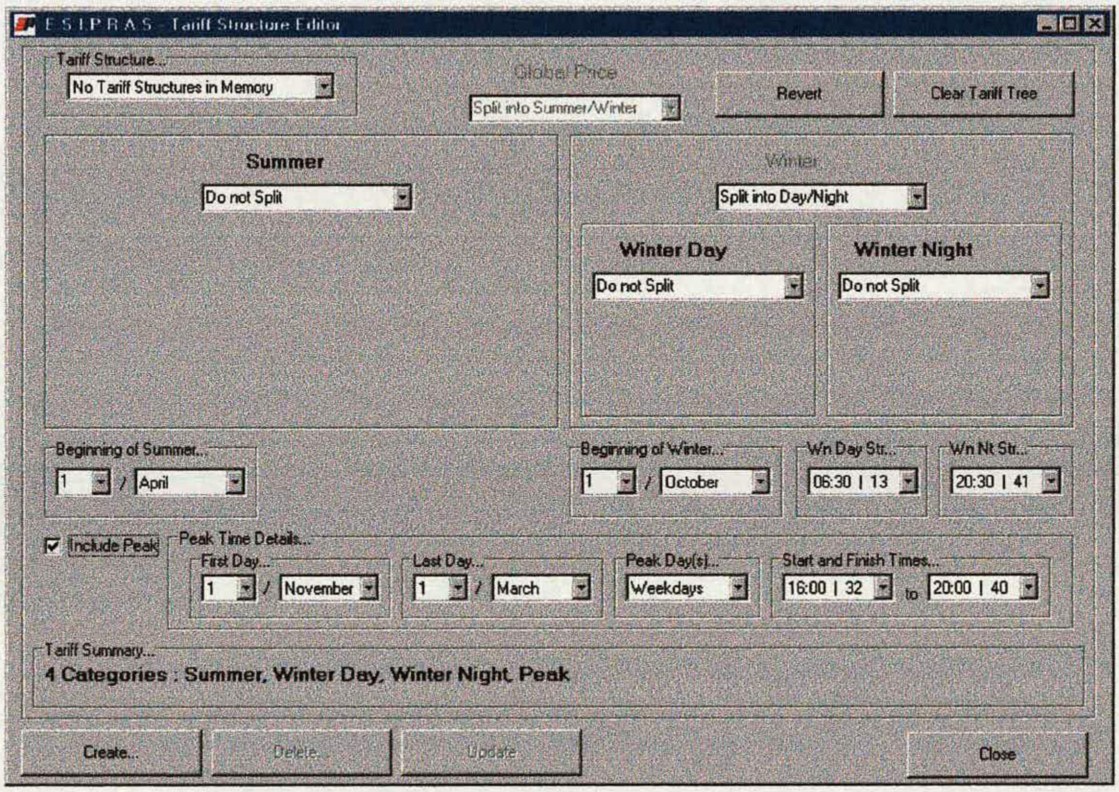


Screen Image 7.10 The *Main* screen after having set the analysis period

The next stage for the analysis is to choose the tariff system to be used in charging the hospital. The analyst selects the relevant item in the *Scenarios* menu to access the *Tariff Structure Editor*, seeScreen Image 7.11

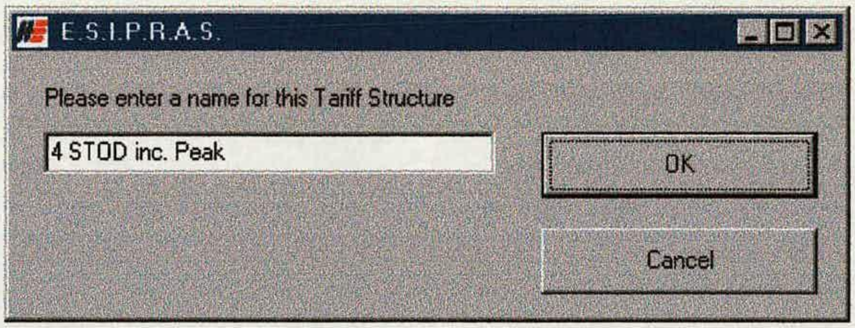
Screen Image 7.11 Accessing the *Tariff Structure Editor* via the *Scenarios* menu

Once in the Tariff Structure Editor, the analyst can specify the four-part seasonal-time-of-day tariff scheme that he wishes to price for, see Screen Image 7.12.



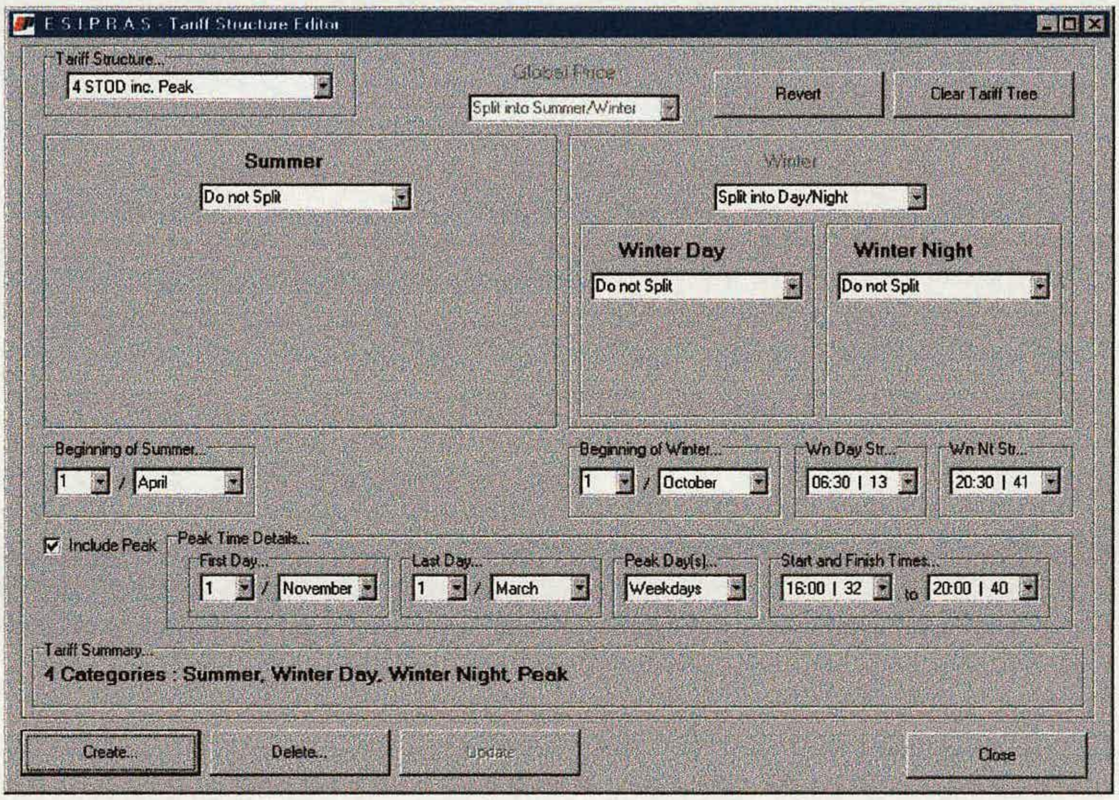
Screen Image 7.12 Specifying a four part tariff structure using the *Tariff Structure Editor*

Once the tariff system details have been entered, the analyst creates the system by pressing the Create button and is presented with the dialogue box, Screen Image 7.13, where he is prompted to name the new tariff structure.



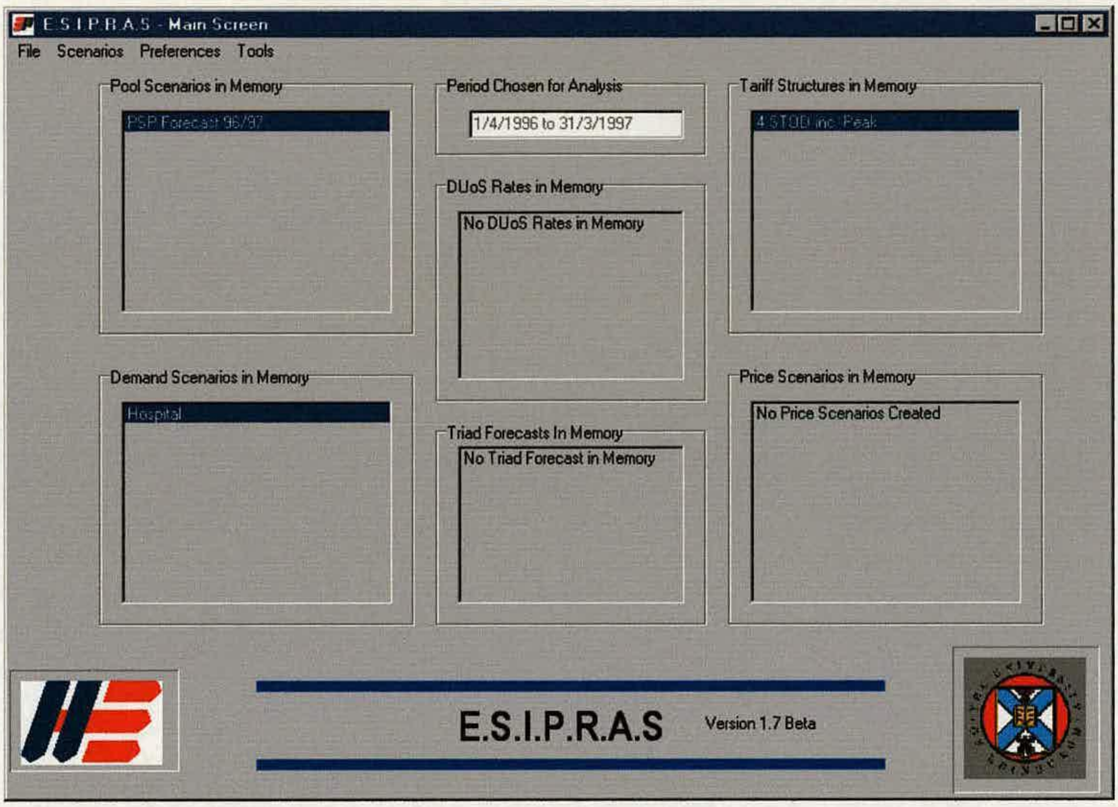
Screen Image 7.13 Naming the new tariff structure after having pressed the *Create* button

The Tariff Structure Editor is then updated to show this new tariff structure in its combo box at the top left of the screen, see Screen Image 7.14.



Screen Image 7.14 The new tariff structure appears in the combo-box in the top left of the *Tariff Structure Editor*

Returning to the Main screen, the analyst notices that it has been updated and now lists the new tariff scheme, see Screen Image 7.15.



Screen Image 7.15 The *Main* screen has been updated to show the new tariff structure is available

7.2.2 Introducing a distribution use-of-system charge

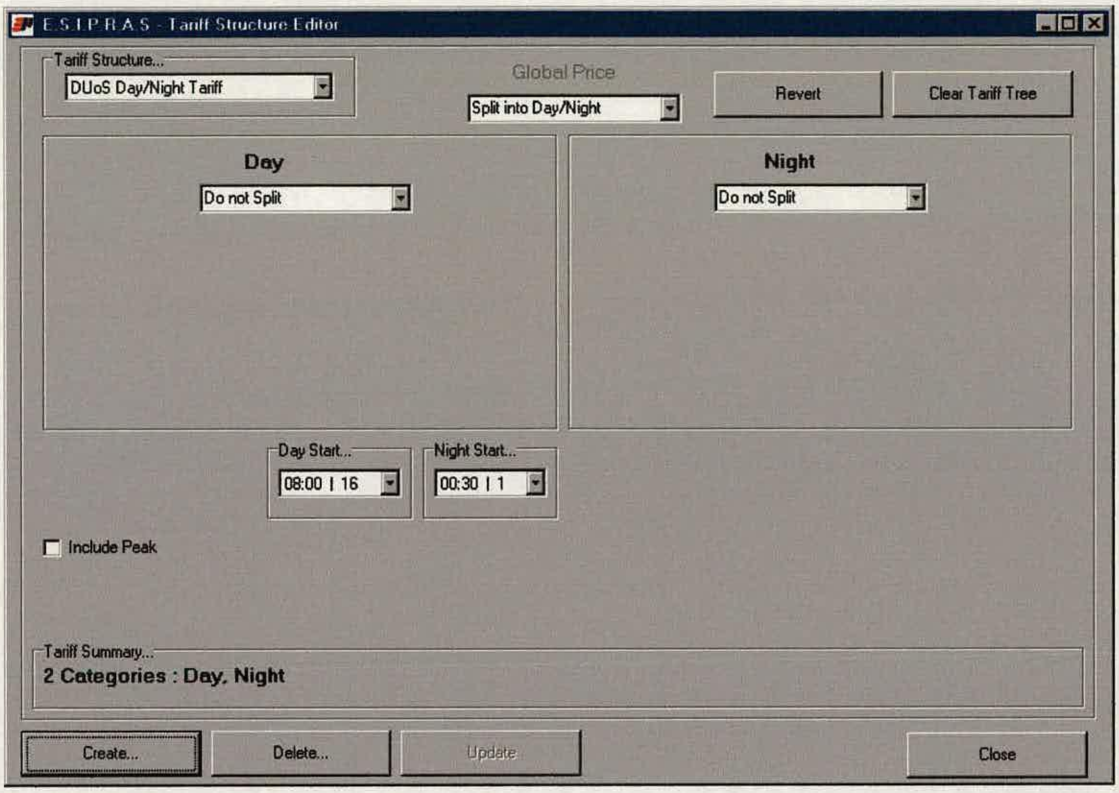
The analyst wishes to include distribution use-of-system (DUoS) charges in the costing, and so has acquired the details of the charges imposed by the region's distribution company, the Midlands Electricity Board. The charges are shown in Table 9.

	LV	HV	33kV
Standing Charge per Month	£7.32	£90.84	£90.84
Availability Charge per kVA per Month	£1.29	£1.12	£0.90
Unit Charge per kWh 00:30 to 07:30	0.196p	0.1p	0.042p
Unit Charge per kWh 07:30 to 00:30	0.818p	0.318p	0.149p

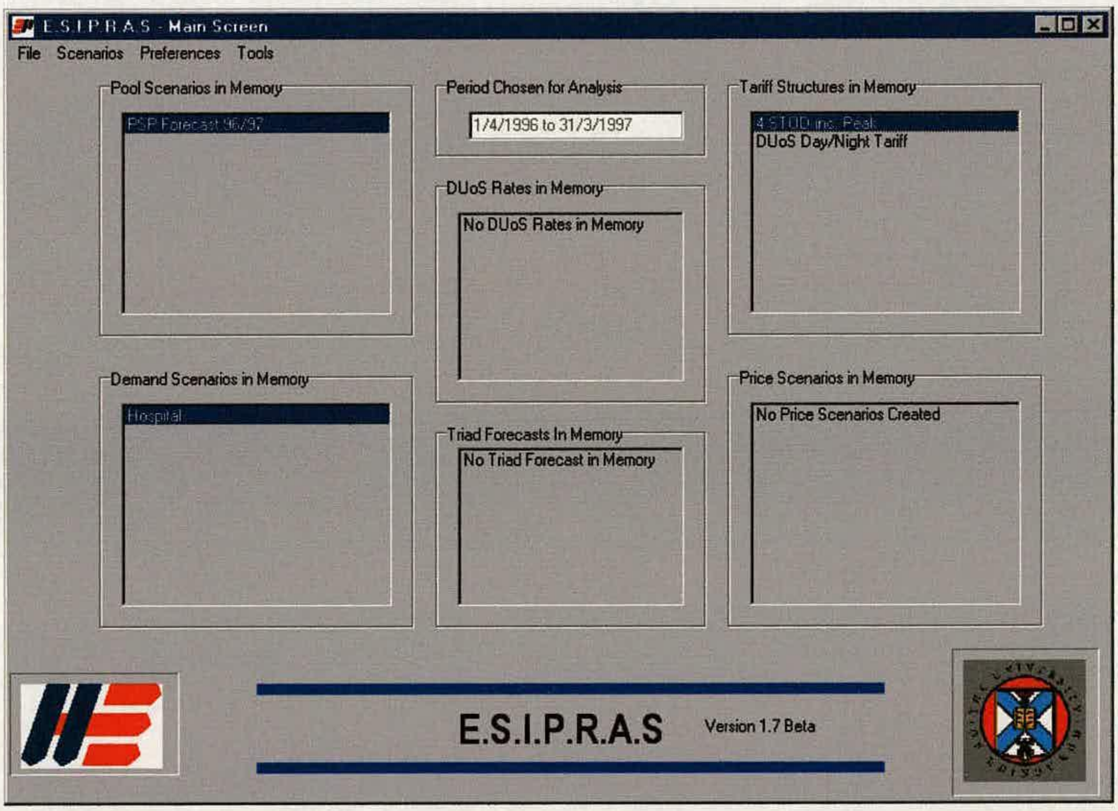
Table 9 Midlands Electricity Board Distribution-Use-of-System Charges

The first step to entering in the details of this charging system is to create a tariff system for the unit charge with the Tariff Structure Editor. The unit charge has two tariffs, one for daytime and one for night. These details are entered into the Tariff Structure Editor and a new tariff scheme is created, see Screen Image 7.16.

The new tariff scheme is then shown on the Main screen as before, Screen Image 7.17.



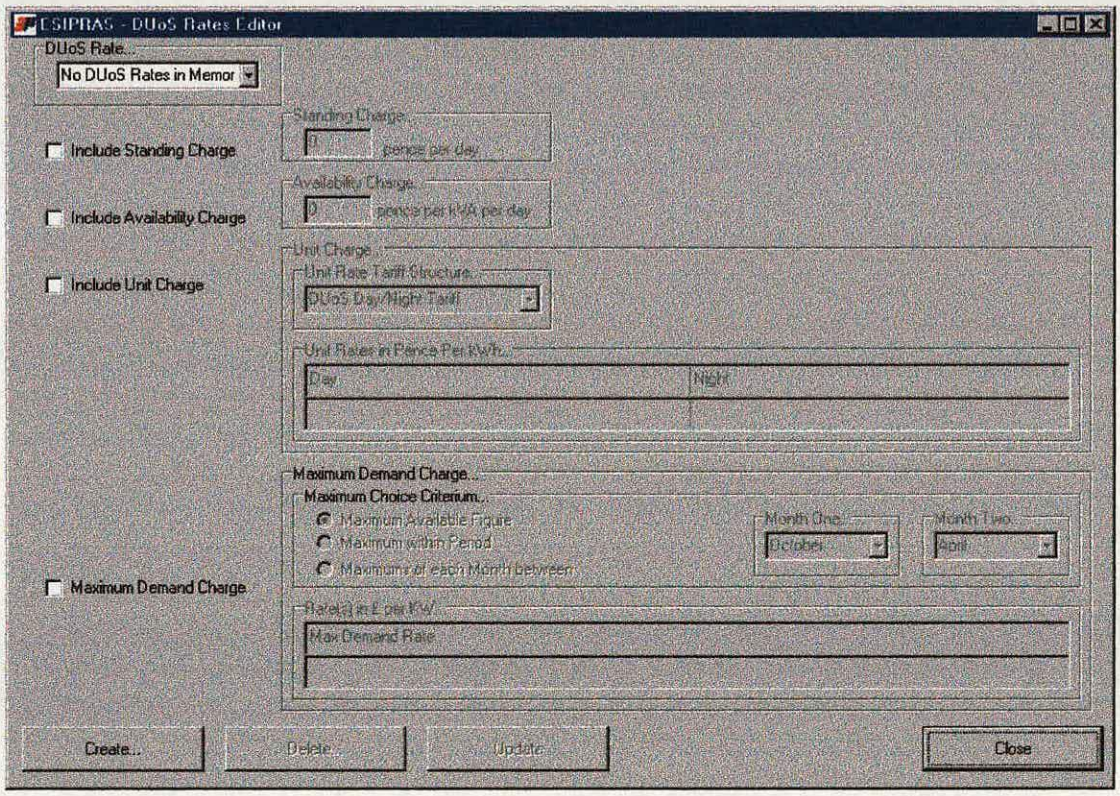
Screen Image 7.16 Using the *Tariff Structure Editor* to specify a tariff scheme for the MEB DUoS rates



Screen Image 7.17 The *Main* screen has been updated to show the new tariff structure

The next step in specifying the DUoS scheme is to access the *DUoS Rates Editor* from the *Scenarios* menu, see Screen Image 7.18. Initially the editor is blank, see Screen Image 7.19.

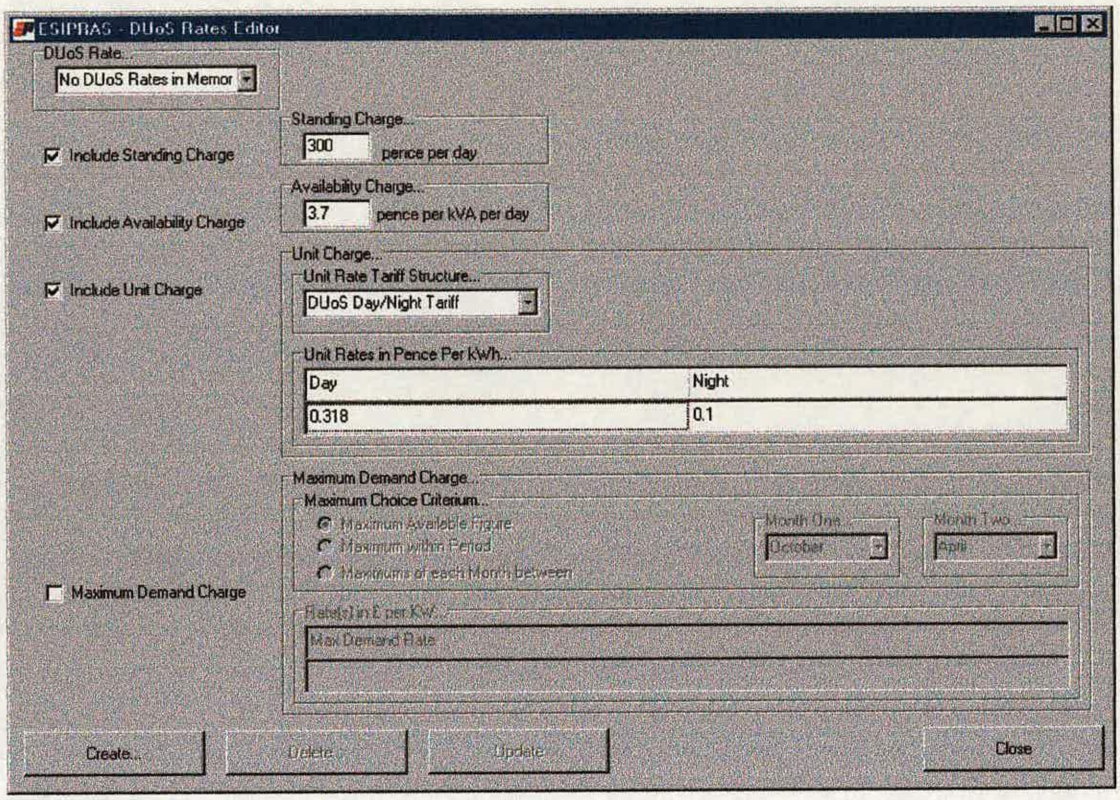
Screen Image 7.18 Accessing the *DUoS Rates Editor* on the *Scenarios* menu



Screen Image 7.19 Initially the editor is blank

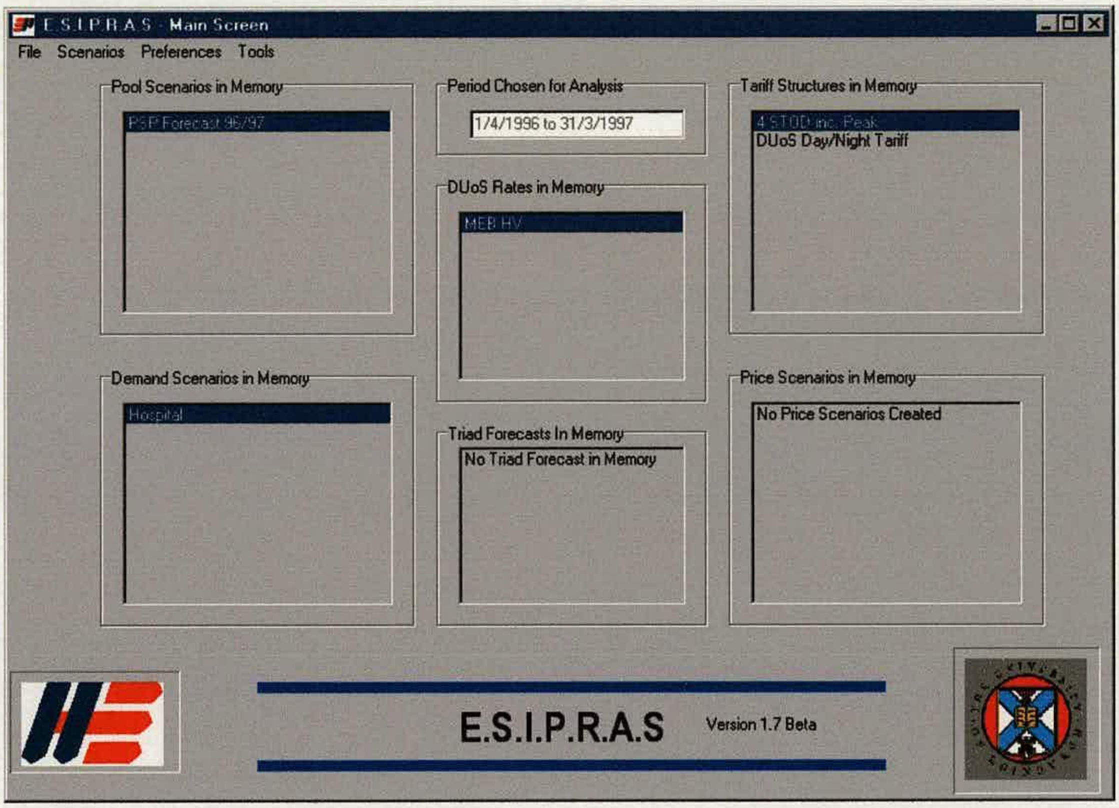
The analyst is now able to enter the details from the MEB's charging system into the editor, see Screen Image 7.20. Some of the values from Table 9 have had to be converted. The standing charge and the availability charge are specified by MEB in £'s per *month*, but have to be converted into *pence* per *day* in the editor. This is achieved by dividing each number by 365/12 and multiplying each result by 100.

Once the details have been entered into the editor, the DUoS rate is created by pressing the *Create* button as before in the *Tariff Structure Editor*. The analyst can now return to *Main* screen.



Screen Image 7.20 Using the MEB rates to create a DUoS cost scheme

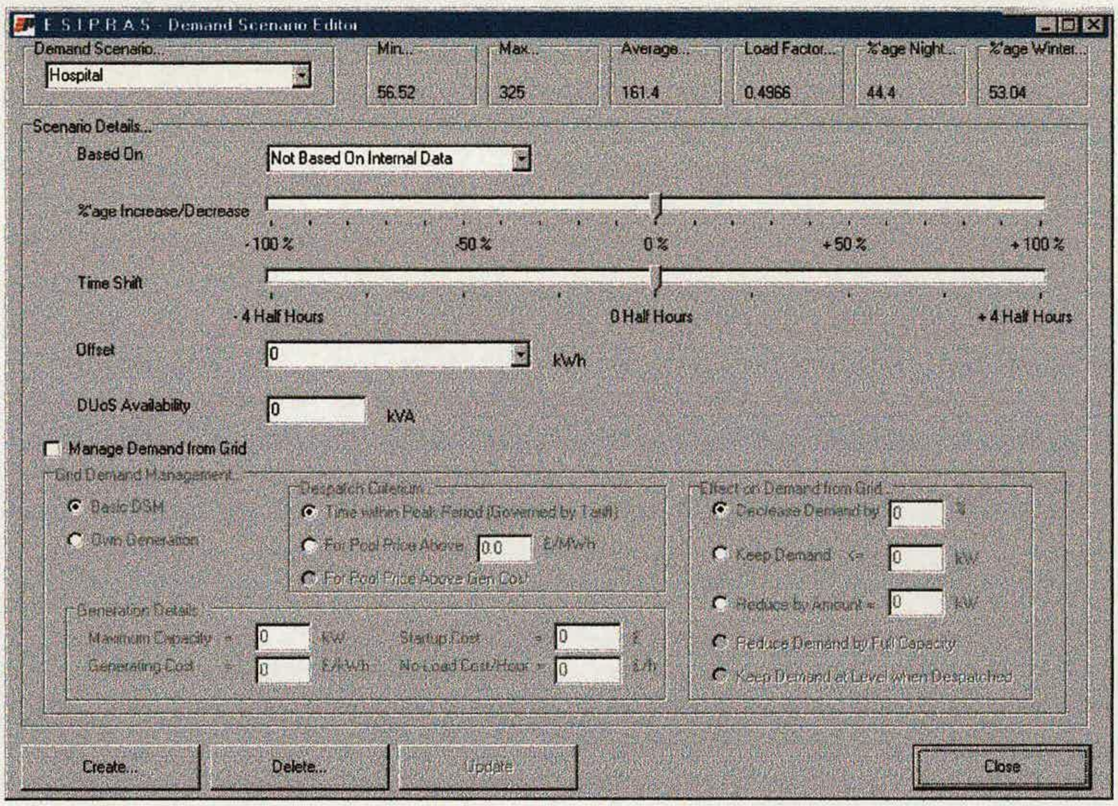
The *Main* screen, in Screen Image 7.21, now reflects the availability of the new DUoS charging scheme.



Screen Image 7.21 The *Main* screen has been updated to show the new DUoS rate system in memory

The DUoS charging scheme includes an availability charge. The availability information needs to be added to the demand scenario. This is achieved by accessing the *Demand Scenario Editor*, see Screen Image 7.23, by selecting the relevant item on the *Scenarios* menu, see Screen Image 7.22.

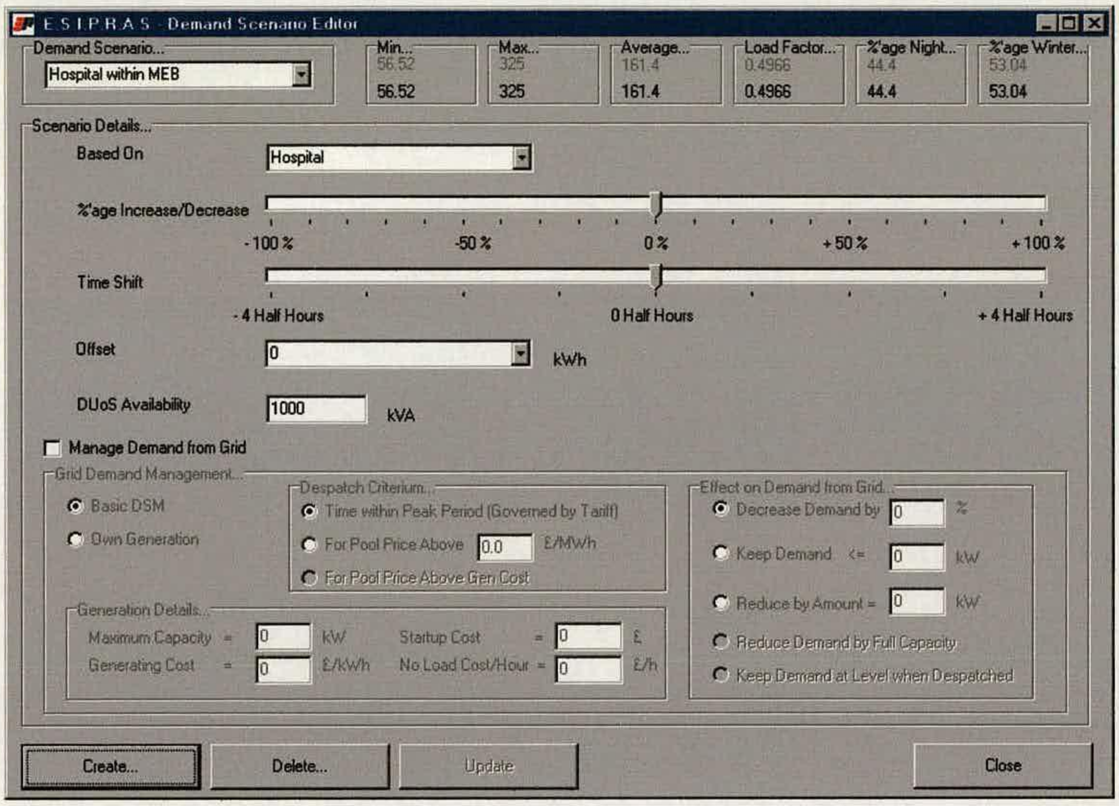
Screen Image 7.22 Accessing the *Demand Scenario Editor* via the *Scenarios* menu



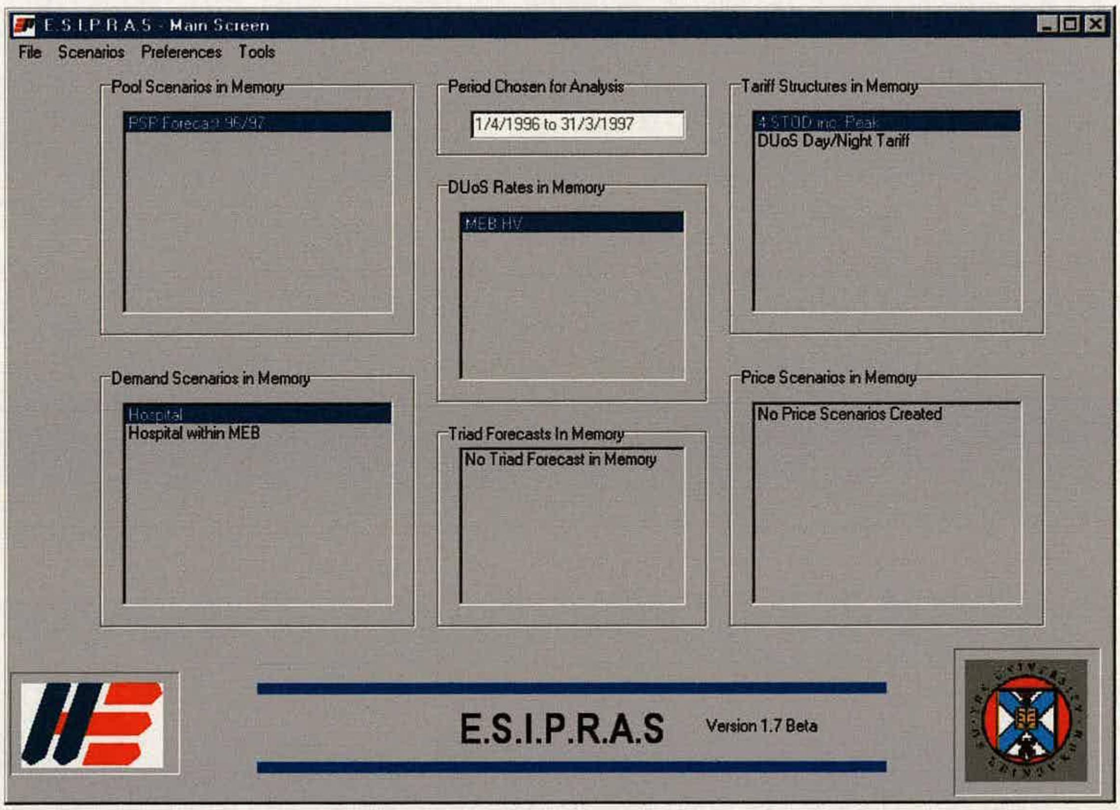
Screen Image 7.23 The *Demand Scenario Editor* showing details for 'Hospital'

Once in the *Demand Scenario Editor*, the analyst can create a new demand scenario, which is identical to the original, except that it contains the availability capacity information, Screen Image 7.24. The analyst has contacted the distributor and discovered that they would agree upon an availability capacity of 1 MVA for the hospital.

Once the analyst returns to the Main screen, he notices that it has been updated and now lists the new demand scenario, see Screen Image 7.25.



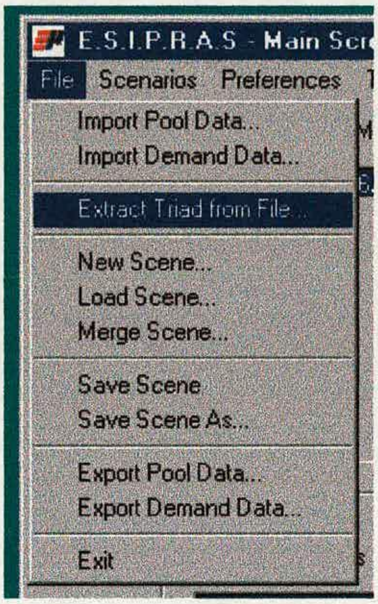
Screen Image 7.24 The *Demand Scenario Editor* after having created a new scenario with an availability figure specified



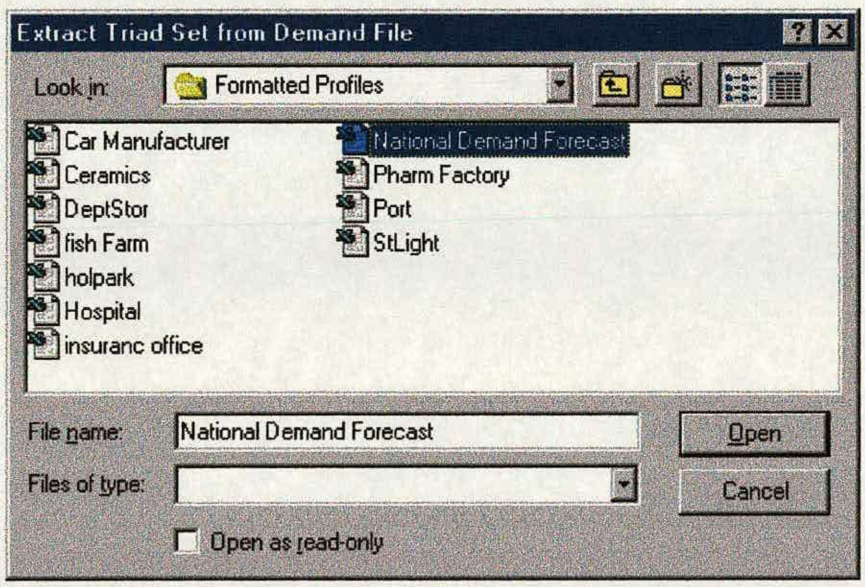
Screen Image 7.25 The new demand scenario is shown on the *Main* screen

7.2.3 Introducing a grid use-of-system charge

The analyst also wishes to include the grid use-of-system charges in his costing. In order to achieve this, the analyst accesses the *Extract Triad from File* command from the *File* menu, see Screen Image 7.26. This leads to an 'Open' dialogue from which the analyst selects a file containing a forecast of national demand for the period of the contract, see Screen Image 7.27.

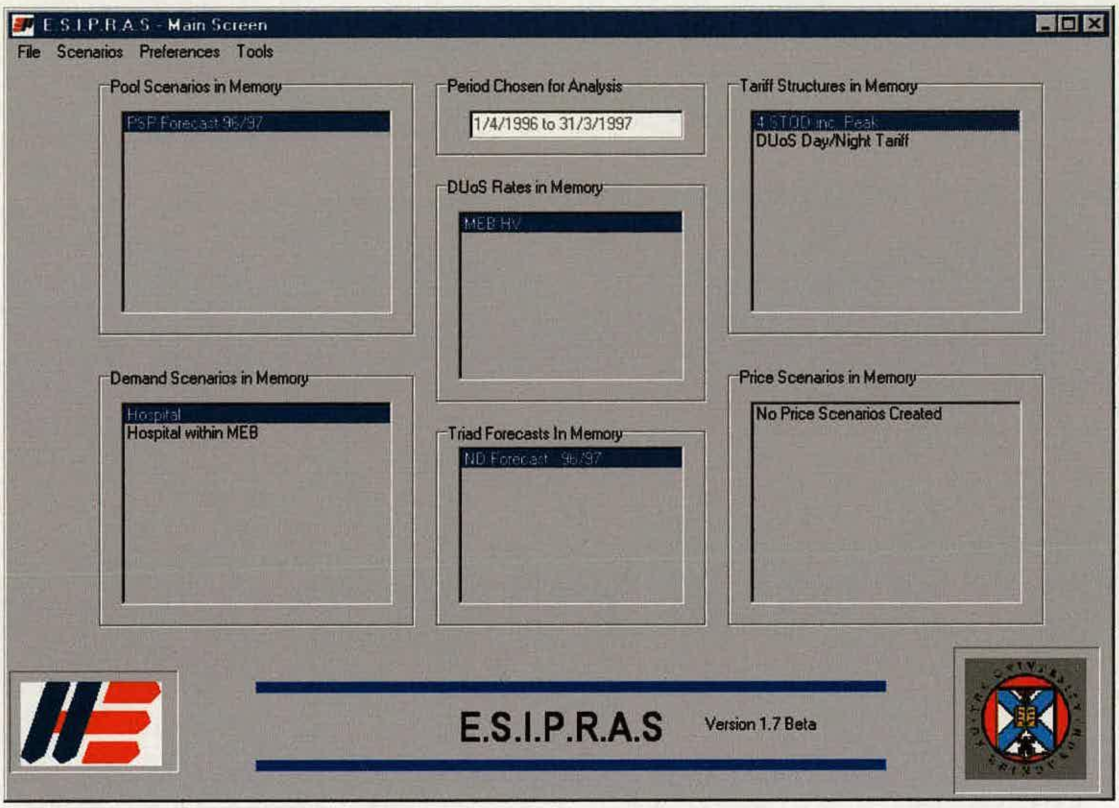


Screen Image 7.26 Extracting a set of Triad dates from a demand profile within a spreadsheet file using the *File* menu



Screen Image 7.27 'Open' Dialogue for extracting a triad set from a demand profile

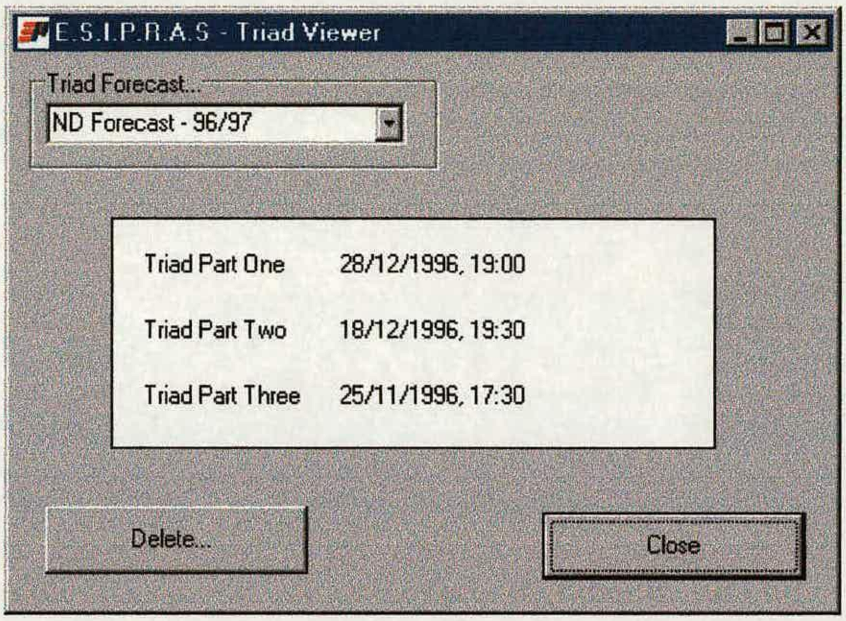
The presence of this triad set is then shown on the Main screen, see Screen Image 7.28.



Screen Image 7.28 The *Main* screen showing the Triad dates scenario in memory

The analyst can inspect the triad set by accessing the *Triad Viewer*, using the Scenarios menu, see Screen Image 7.29. The Triad Viewer, in Screen Image 7.30, displays the triad periods within the set extracted from the national demand forecasted.

Screen Image 7.29 Accessing the *Triad Viewer* from the *Scenarios* menu

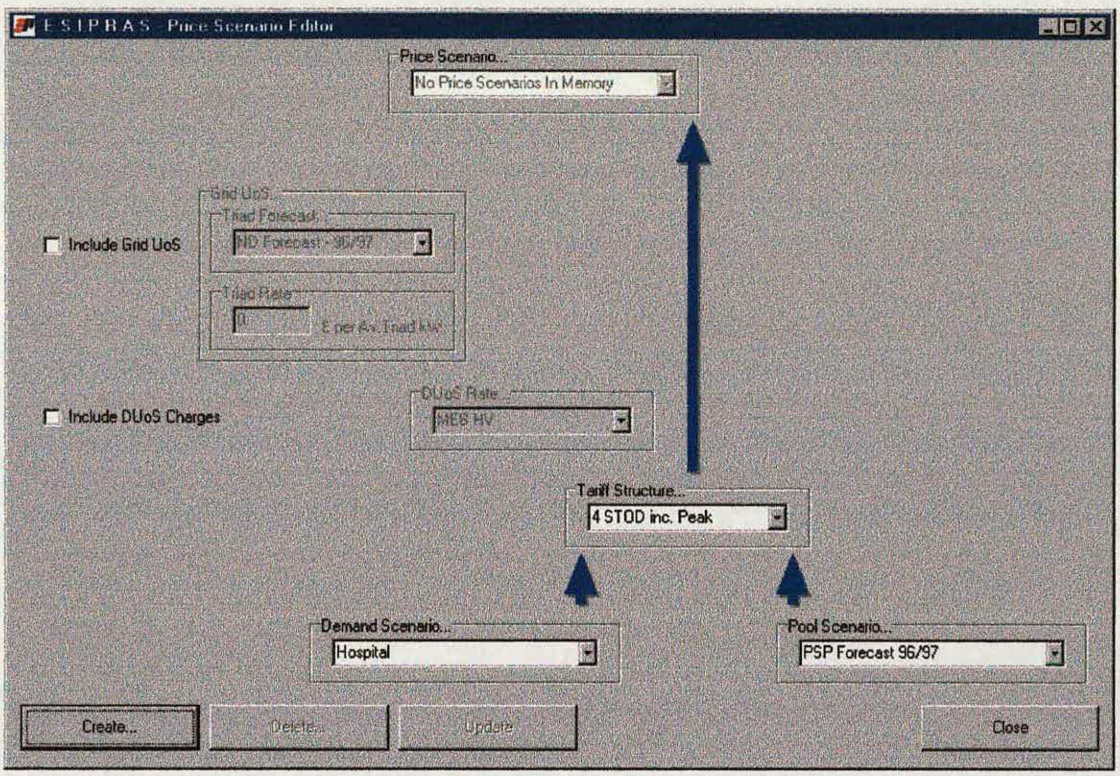


Screen Image 7.30 The *Triad Viewer* showing the system's calculated Triad from the specified file

7.2.4 The price calculation

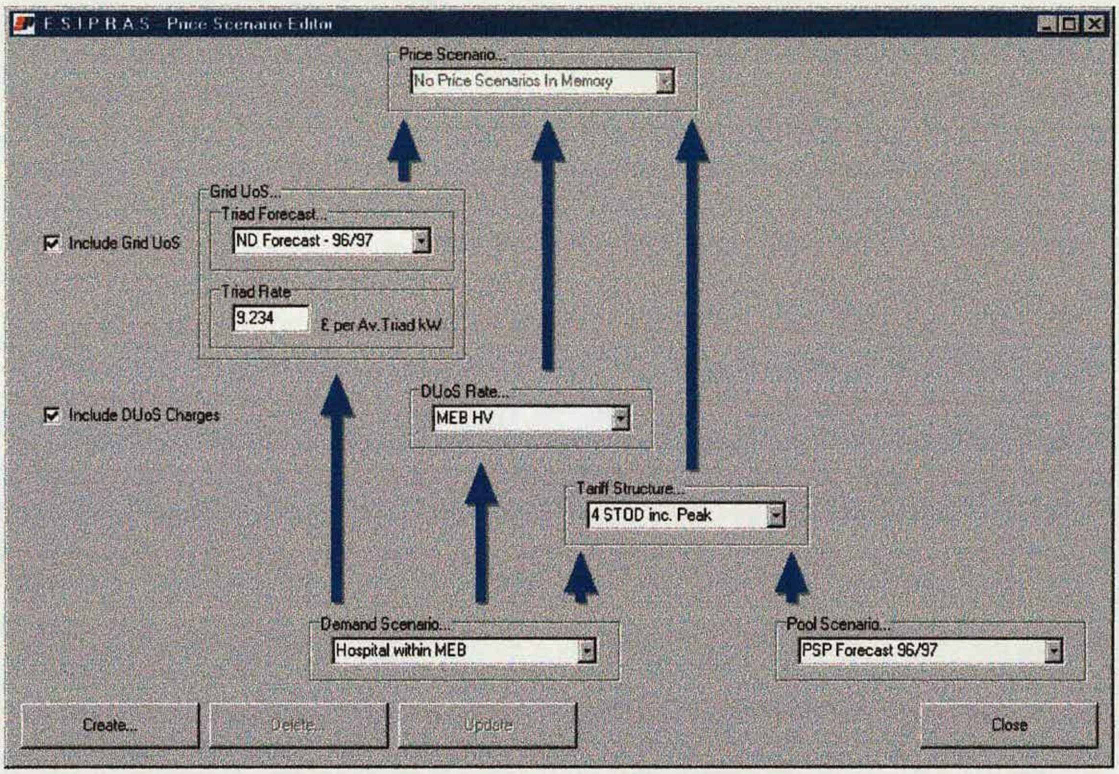
Now, the analyst is ready to calculate the set of tariffs and charges for the hospital. This begins by the analyst accessing the *Price Scenario Editor*, see Screen Image 7.32, from the item on the *Scenarios* menu, Screen Image 7.31.

Screen Image 7.31 Accessing the *Price Scenario Editor* from the *Scenarios* menu

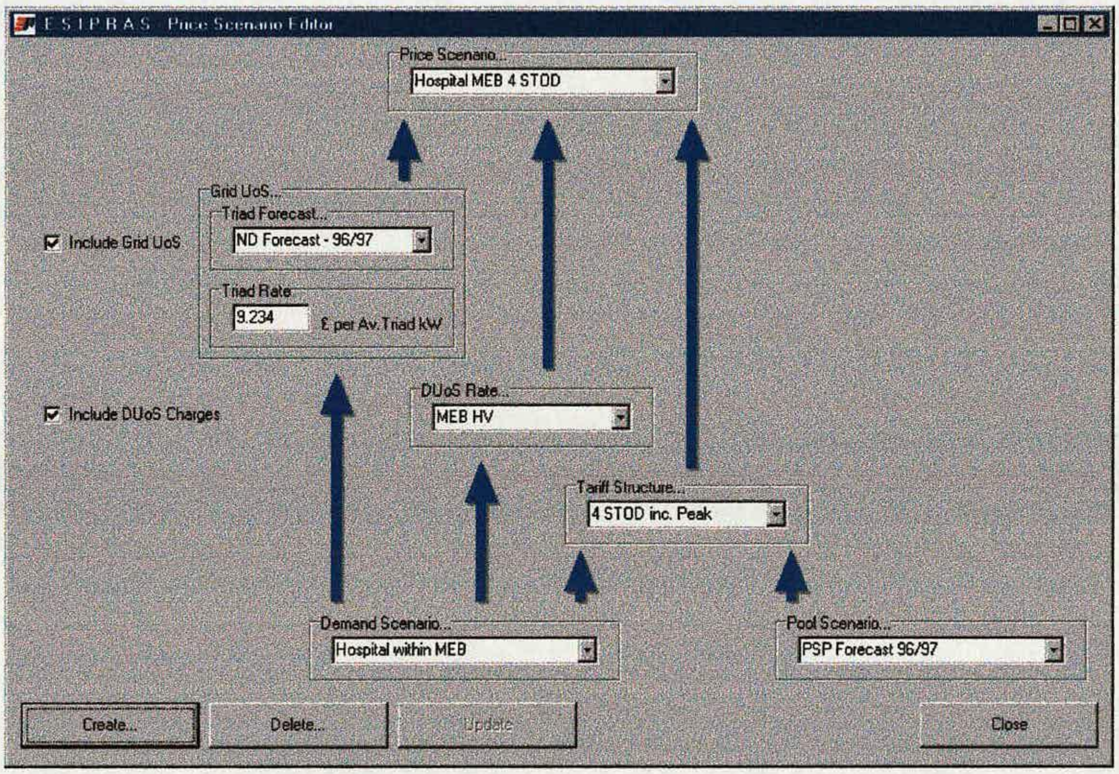


Screen Image 7.32 The *Price Scenarios Editor* upon entry

The editor needs to be filled with the relevant details of the analyst costing run. The analyst specifies that he wants both a grid use-of-system charge, acquired from NGC, and a DUoS charge to be included in the price. The analyst selects the demand scenario with the availability capacity information that he created earlier. The complete details are shown in Screen Image 7.33, and once the user has created and named the price scenario, the screen looks like Screen Image 7.34.

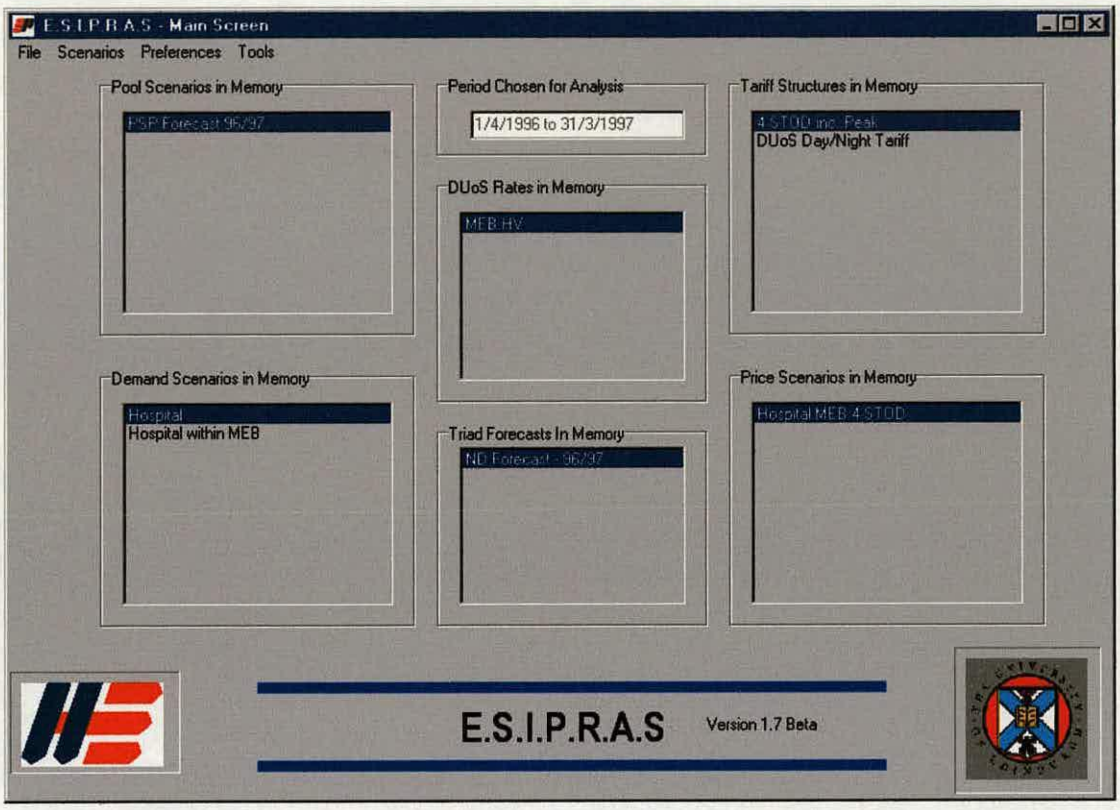


Screen Image 7.33 Specifying a price scenario with a demand profile, a Pool price forecast, a Triad charge, and a DUoS rate



Screen Image 7.34 The *Price Scenario Editor* after a new price scenario has been created and calculated

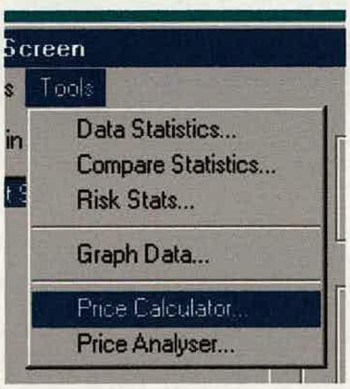
Upon returning to the *Main* screen, the analyst notices that it has been updated with name of the new price scenario.



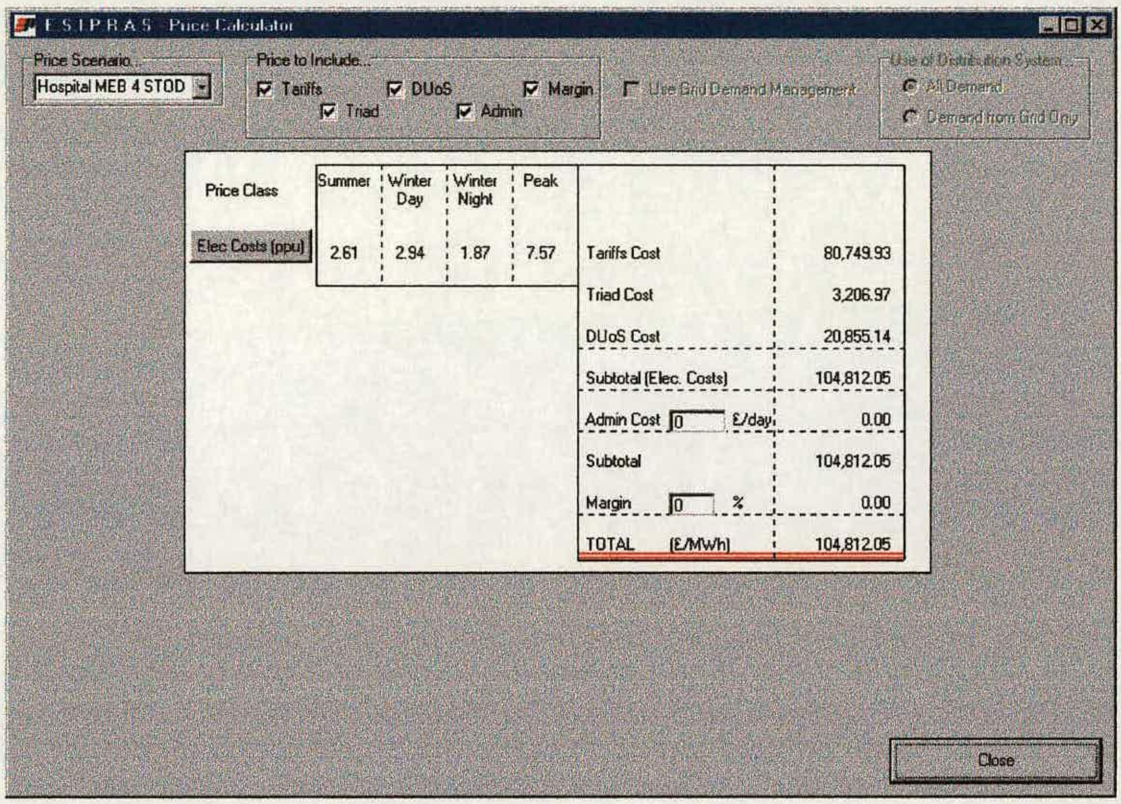
Screen Image 7.35 The new price scenario is reflected in the display on the *Main* screen

7.2.5 Displaying the price scenario

The next stage is for the analyst to inspect the results of the price scenario. These can be viewed on the Price Calculator, accessed via the *Tools* menu, see Screen Image 7.36.

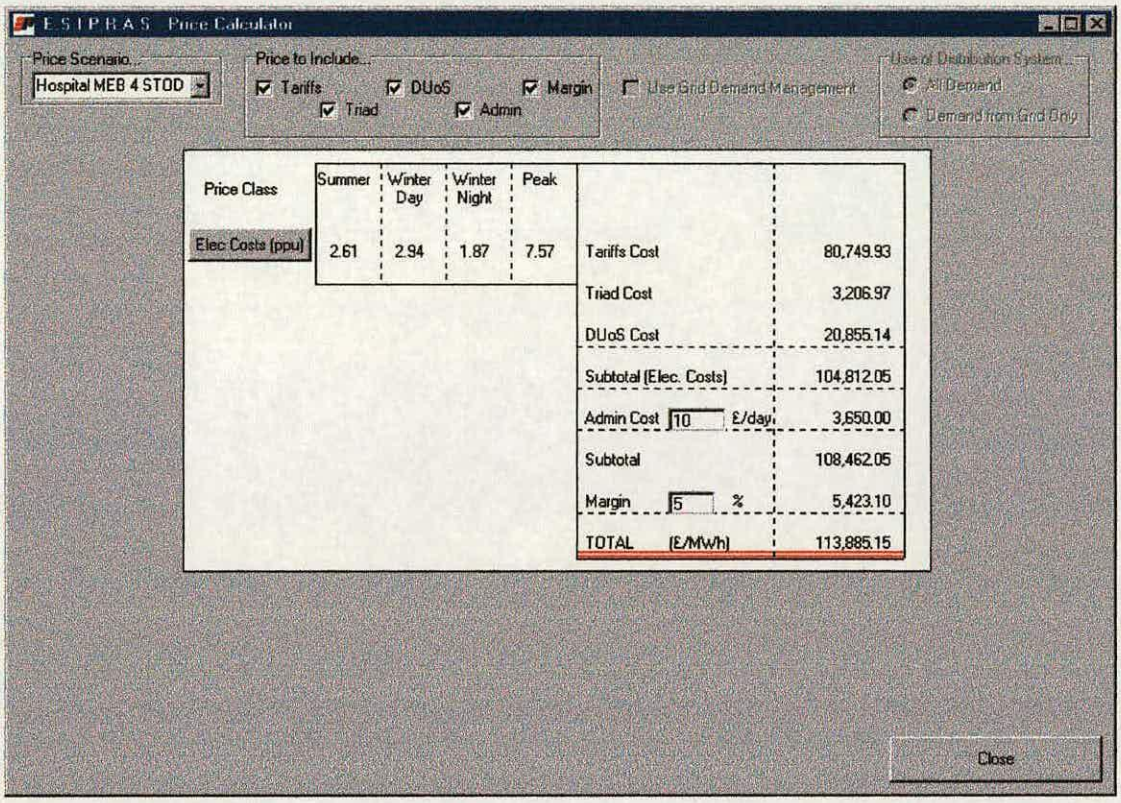


Screen Image 7.36 Accessing the *Price Calculator* via the *Tools* menu



Screen Image 7.37 The *Price Calculator* on entry

The Price Calculator, in Screen Image 7.37, shows a run down of the costs that have been calculated for the hospital. To these costs, the analyst can enter an administration rate, in £'s per day, and a margin, in %. The results of this are shown in Screen Image 7.38.



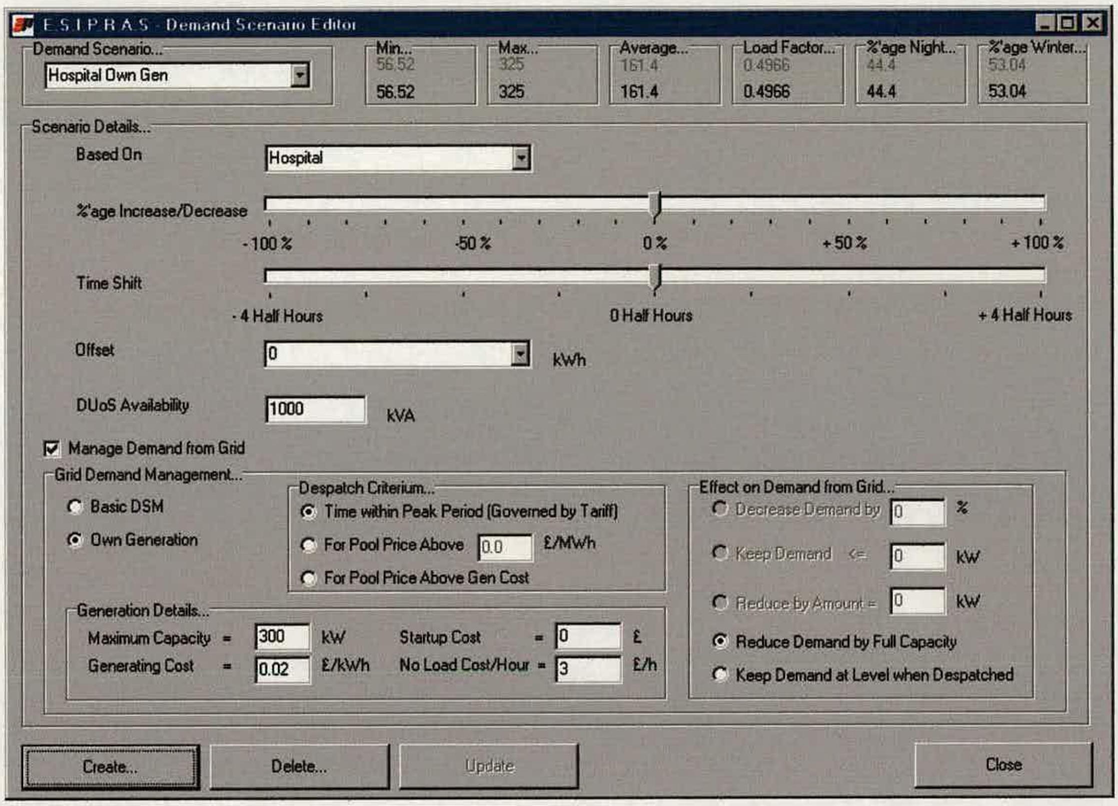
Screen Image 7.38 The *Price Calculator* after having specified an 'Admin' rate and a Margin

7.2.6 Specifying On-Site Generation

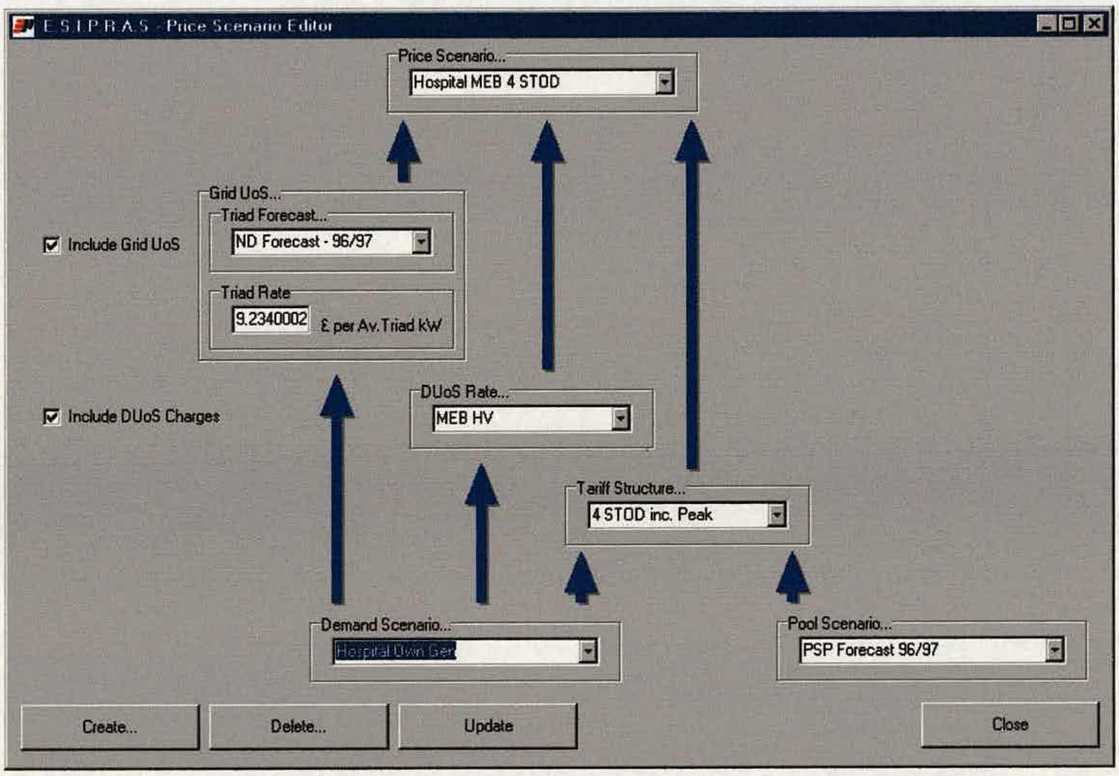
The analyst now wants to examine the feasibility of using an embedded generation facility to supply the hospital. This may provide lower overall electricity costs if the hospital generates some of its own electricity during peak periods to avoid high Pool prices. The analyst begins by specifying a new demand scenario, based on the existing forecast demand profile of 'Hospital', whilst adding a specification for an on-site generation facility, see Screen Image 7.39. The demand scenario shown here depicts the hospital connected to an embedded 300 kW generation set. The set is to be despatched during all peak periods when it is to work at full capacity. The times of these peak periods are governed by the tariff structure that is used to create the price scenario. The *Start-up Cost* is left at zero, since the analyst decides not to incorporate any capital costs at this stage.

Only when the price scenario is calculated on the *Price Scenario Editor*, is the effect of this Grid Demand Management strategy also calculated and placed in a new demand scenario for examination. A set of prices is calculated based on the new demand pattern.

Next, the analyst calculates a new price, see Screen Image 7.40

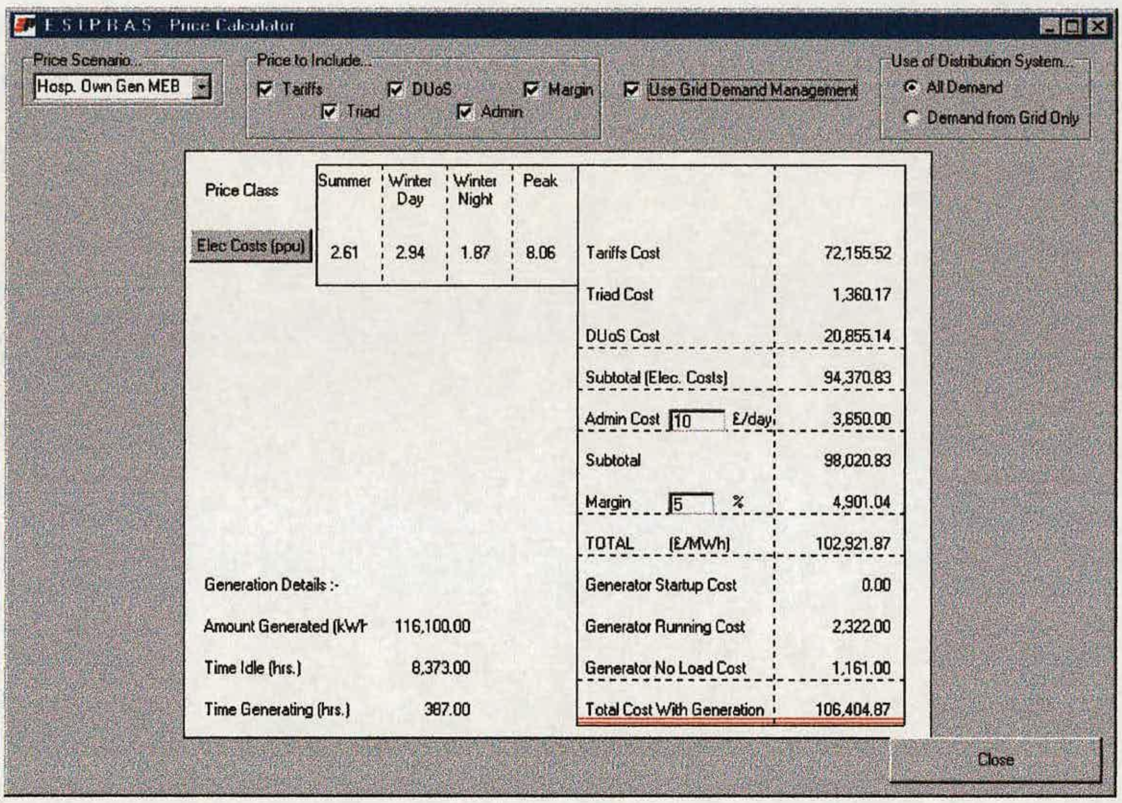


Screen Image 7.39 Specifying a demand scenario with an embedded generation facility

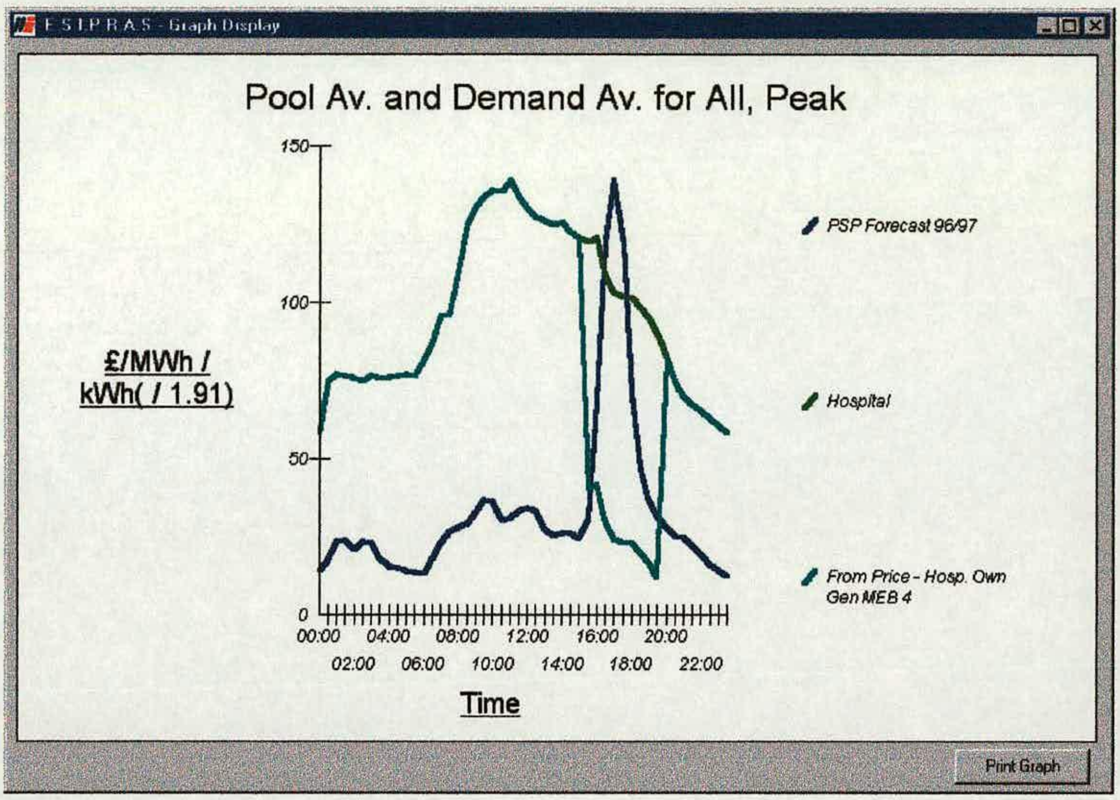


Screen Image 7.40 Creating a new price scenario with the new demand scenario

Finally, the analyst examines the results in the *Price Calculator*, Screen Image 7.41. The radio box choice at the top right of the screen marked *Use of Distribution System...* is set to *All Demand*. This treats the electricity transferred to the hospital from the embedded generator as though it is subject to the same DUoS rates as that taken from the grid, since the embedded generator is connected to the hospital via the distribution system. The costs can be compared with Screen Image 7.38. It seems that, whilst not taking capital costs into account, the option is promising. The effect of the despatch strategy specified in the demand scenario is shown in the Graph Display screen in Screen Image 7.42.

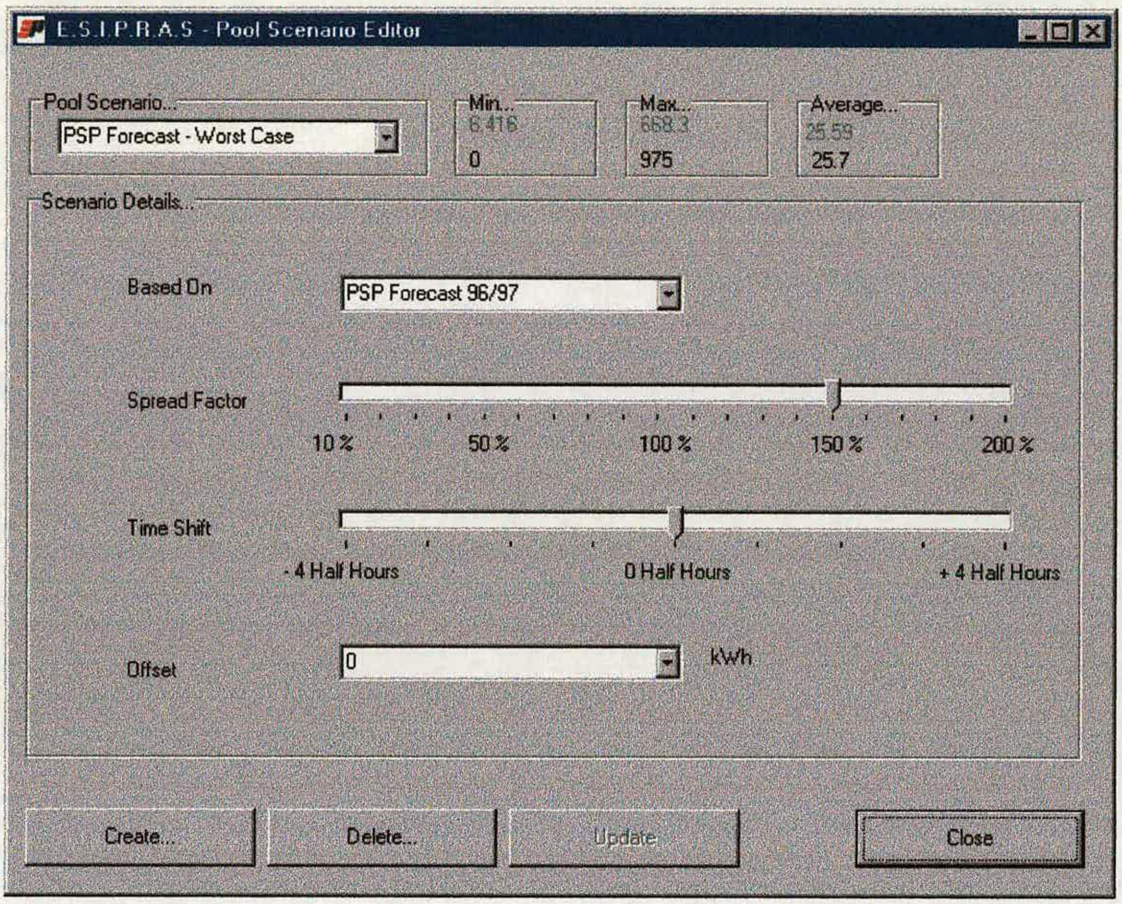


Screen Image 7.41 The *Price Calculator* displaying the alternative scenario with on-site generation



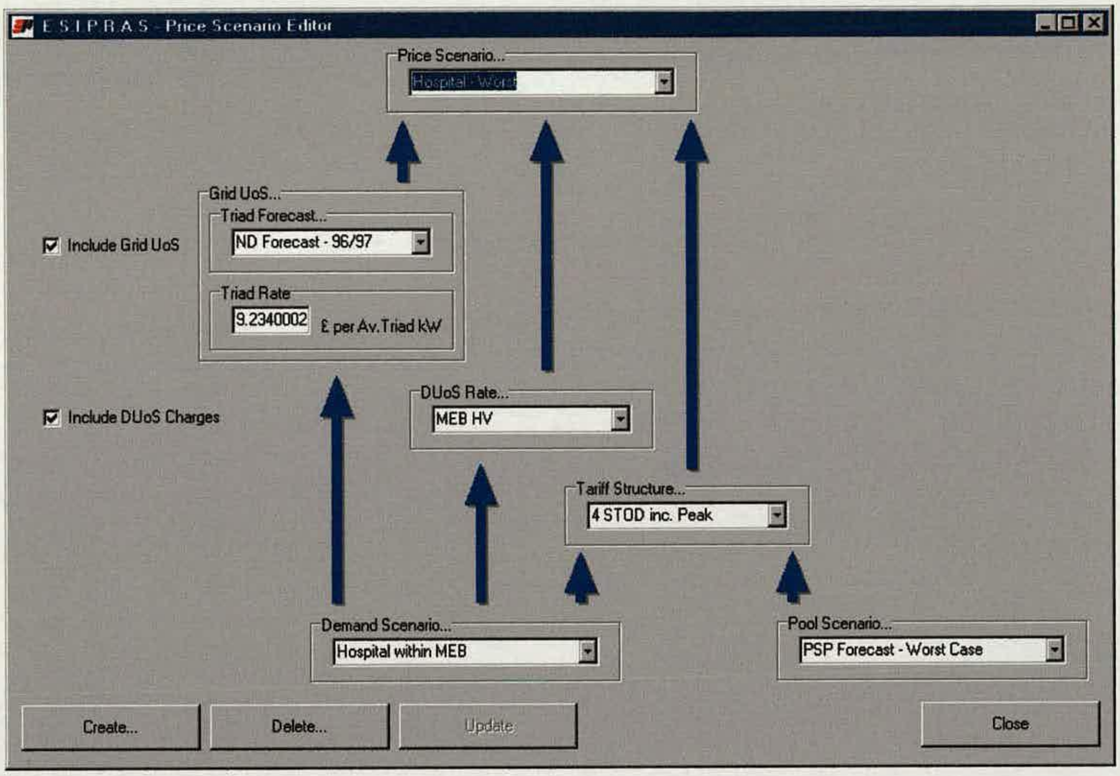
Screen Image 7.42 *ESIPRAS*'s *Graph Display* showing the dip in the demand from the grid during the 'peak' period

7.2.7 Examining the effect on a contract of a worst case Pool price scenario



Screen Image 7.43 Specifying an alternative 'Worst-case' Pool scenario with higher price 'volatility'

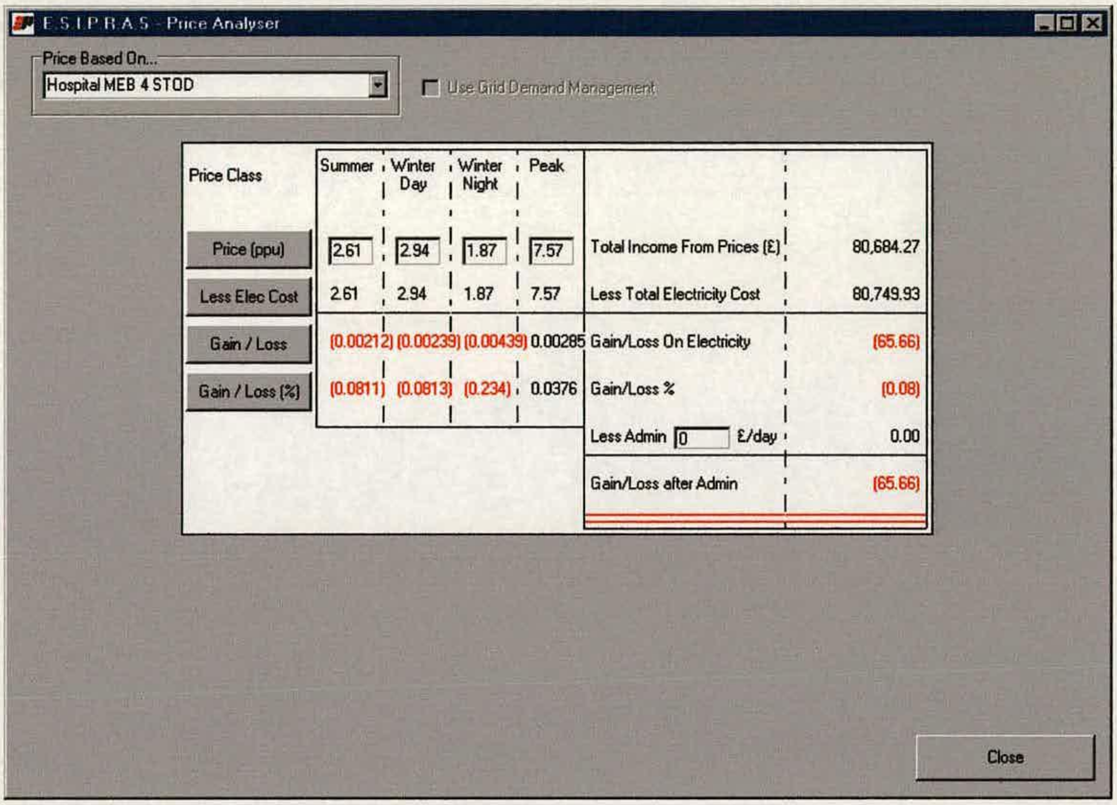
The analyst decides that he wishes to examine the effect of a worst-case Pool scenario on the performance of a Supply contract with the hospital. Firstly, he creates a new Pool price scenario that he believes will represent the worst case. To achieve this, the analyst creates a new Pool scenario based on his existing forecast, but with a large spread factor, see Screen Image 7.43. Subsequently, the analyst creates a new price scenario based on this new Pool forecast, Screen Image 7.44.



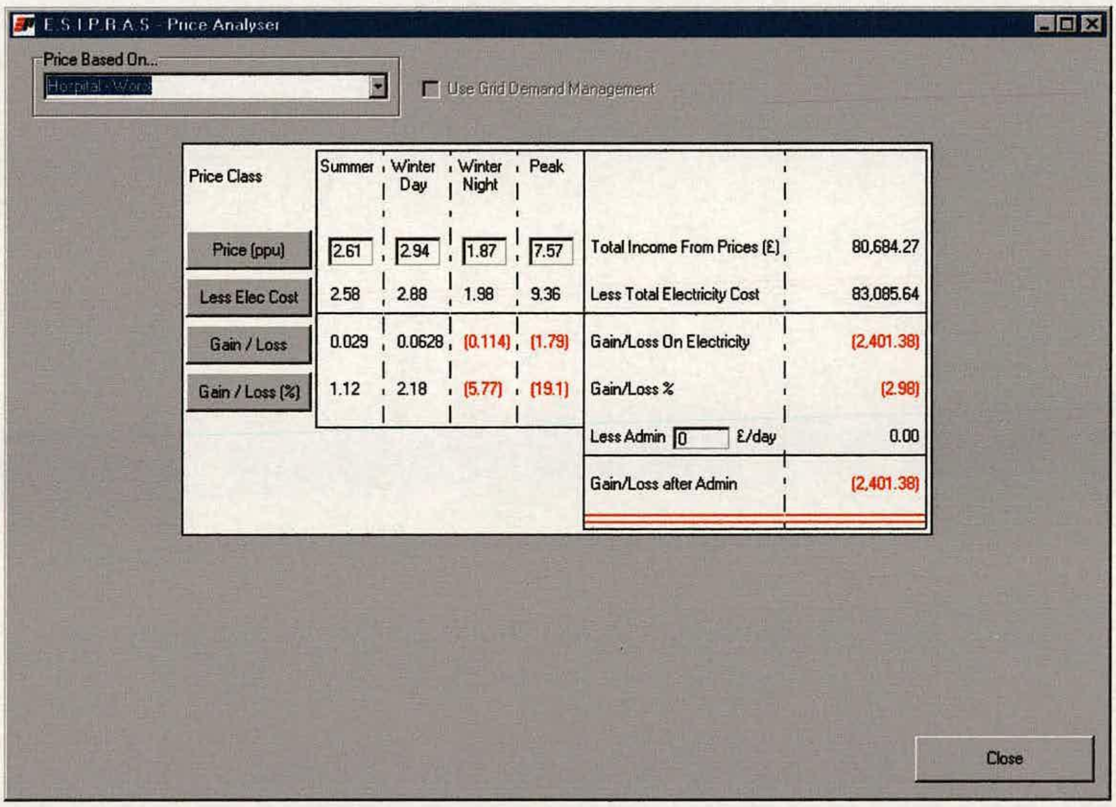
Screen Image 7.44 Specifying a new price scenario with the 'Worst-case' Pool price scenario

Next, the analyst enters the *Price Analyser*, and fills the price edit boxes with tariffs that match those calculated to pay for the expected electricity costs , those of the original scenario, see Screen Image 7.45. The calculation does not break-even exactly as the electricity tariffs are only displayed to two decimal points of accuracy.

Now, the analyst changes the combo box to select the new, 'worst-case' price. The figures in the edit boxes remain the same, so that the user can see the fiscal effect of the 'worst-case'scenario. The contract would lose about 3 % of its turnover on the basic electricity charges in this case.



Screen Image 7.45 Setting up the price edit boxes with the 'break-even' expected prices



Screen Image 7.46 Comparing the expected prices with the worst case scenario

Chapter 8 Design Notes

8.1 *Introduction*

This chapter contains design notes for various parts of *ESIPRAS*. The design notes provide more detail on the exact function of, and/or discussion about the use of, important parts of the system. For each function discussed, opportunities for additions and further work to enhance *ESIPRAS* are described.

8.2 *Importing Data*

8.2.1 Spreadsheet format

At the beginning of the project, most of the customer demand and Pool price data (PSP) used by the Supplier was kept in *Lotus 1-2-3* format spreadsheet files. It was also clear that files might be kept in *Excel* format as an alternative. Therefore, *ESIPRAS* was designed to be able to import information kept in these formats. The use of OLE automation has meant that it can import data in either format seamlessly. This method was also convenient as *ESIPRAS* was being created off-site and it was useful to be able to develop and test the system with files available conveniently on portable floppy disks.

The data within each of the spreadsheet files must be arranged in a standard way, in order for *ESIPRAS* to be able to find it and load it into its internal memory. *ESIPRAS* was designed so that it used what seemed to be the most popular cell arrangement that the Supplier was using for his files. These cell arrangements for demand files and for Pool price files are detailed in Appendix A. Any file that the analyst wishes to import must conform to these cell arrangements or *ESIPRAS* will not be able to import the data successfully without error.

The 'number of days' values within the spreadsheets ensure that *ESIPRAS* does not need to search the spreadsheet to find the end of the data for itself. All that needs to be specified is the location of the start of the data array, and, in another specified cell, the number of days represented in the file. Originally, *ESIPRAS* was programmed to look for the end of the data – *ESIPRAS* looked down the 'dates' column until it found a gap. Unfortunately, this made data importation very slow due to the slow performance of OLE automation. Therefore, this method was rejected in favour of the system of requiring the file to explicitly specify the number of days within its contents.

Disadvantages of the present method of importing data include:

- It can be both time-consuming for an analyst to load a number of different files on different floppy disks.
- Depending on the source of the data, the files may have to be adapted to meet the standard cell arrangement that *ESIPRAS* expects. The analyst must always add the 'number of days'

information to a file in preparation for its use in *ESIPRAS*. This is both time consuming and an added chore. One fail-safe solution might be to extent *ESIPRAS* so that if it does not find the 'number of days' information, it would search the spreadsheet for the end of the data, whilst warning the user that the data import would take less time if the file was adapted to include the information. *ESIPRAS* could then automatically re-save the data with the correct value in the right location, so that a subsequent importation of the same file would be carried out much faster.

- Presently, the cell locations where *ESIPRAS* expects to find information are fixed and 'hard-wired' into the software within its source code. It would be more elegant to provide the user with a set of preferences within a user-friendly window of the system that would allow him to customise where *ESIPRAS* should look. This forms another recommendation for further work.

The time taken to import all the data needed within an analysis session is indeed an issue. This issue is to some extent addressed with *ESIPRAS* providing the option of saving its memory into a 'scene' file. This allows the analyst, for example, to save a set of popular site profiles, tariff structures or Pool data for quicker retrieval later. Scene files are significantly faster to load than spreadsheet files, as *ESIPRAS* does not need to communicate with *Excel* to load any data. However, scene files are a non-standard file type designed only to be used with *ESIPRAS*.

Another major improvement could be made to *ESIPRAS*. Often, the Supplier will keep customer profiles and forecasts on a database. *ESIPRAS* could be extended to allow the analyst to import data from such a database over a network. This would save the analyst a lot of time.

8.3 GMT vs. BST data

In summer, UK clocks are adjusted to show British Summer Time (BST). The clocks are shifted by one hour, so that there is one extra hour at the end of a day in October and one less hour in the morning on a day in March. In order to simplify the design and use of the software, all times are expressed and interpreted as if in GMT. This means that all times used to specify periods within tariff structures, and all imported data, must be converted into GMT format first. This system will affect price calculations in minor ways that an analyst should be aware of.

If the analyst uses a tariff structure in which there is no distinction between daytime and night-time start times between summer and winter, the summer demand will be shifted so that GMT daytime will, in effect, cover one hour of summer night-time and vice-versa. However, this effect can be removed if the analyst divides the tariffs into summer and winter prices, by defining the start of daytime and night-time for both seasons.

Some parts of price calculation will remain completely unaffected. For example, Peak tariffs are not generally affected since they are usually only specified for winter months, when GMT is used for both time systems.

8.4 The Pool Scenario Editor and Volatility Change

One of the main issues in analysing the feasibility of customer contracts, is the effect of the behaviour of Pool price during peak periods, mainly in winter, on the expected performance of the contract. As discussed in section 4.6.1.2, the high Pool prices during the peak periods during winter do contribute significantly to the overall electricity cost to the typical customer, since they can represent prices with ratios of up to 10:1 to a day's remaining periods' average price. *ESIPRAS* provides a means of adapting imported Pool forecasts to represent different scenarios. One feature that was seen as desirable was a method of adapting Pool forecasts so that the prices during peak periods could be increased whilst altering prices during the rest of the day in a sensible way that would reflect empirical behaviour. This would allow an analyst to consider best and worst cases of peak Pool price behaviour. To do this thoroughly would require answering the question:

"When peak Pool prices go up by a certain amount, what happens to prices during the rest of the day?"

The solution is not trivial. It appears that the distribution of prices varies between different half-hours of the day. In particular, the distributions of Peak prices are very different to the distributions of off-peak prices, see Figure 11.

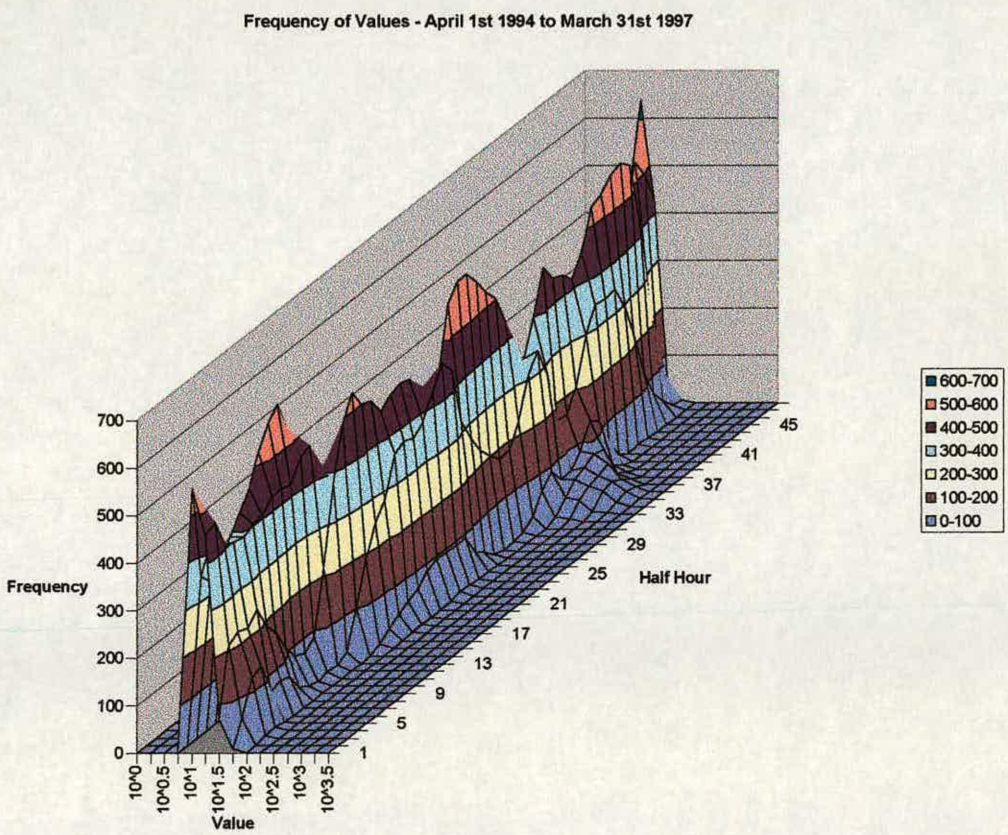


Figure 11 Graph showing frequencies of price values for each half-hour, log scale.

The historical relationship between changes in prices during peak periods and those during the rest of the day could be modelled in order to find some method of changing volatility sensibly across the day. The model might use a simple linear relationship, or a more complex one. It becomes apparent, by simple inspection, that this relationship is likely to be highly non-linear

It was decided that such a detailed analysis was outside the scope of this project. Instead, *ESIPRAS* provides a much simpler, if more crude, method to adapt prices to analyse the effects of high peak prices.

A method was sought to provide:

- A predictable effect on the data which would be easily comprehended by the analyst
- A reasonable approximation of empirical behaviour. In particular, when peak prices go up, off-peak prices should change very little.
- A system that was quick to employ

The method implemented, at this stage, allows the user to increase or decrease the volatility of prices by a certain degree. This is achieved in the following way:

5. The analyst creates a new scenario in the usual way, by pressing the 'Create' button on the Pool Scenario Editor screen, after having chosen which forecast scenario is to be adapted and the variables he wishes to change. In particular, he can supply a factor by which spread of the original forecast will be increased, to create a reduction or increase in volatility.
6. *ESIPRAS* calculates a mean price for each half-hour using the whole original forecast as a basis for its statistics.
7. *ESIPRAS* will then adapt the prices. For each price, it calculates the difference between it and it's half-hour mean. It then creates a new price that equals the mean of that half-hour plus that difference multiplied by a factor. If, however, the new price is negative, the new price is set to zero. *ESIPRAS* then warns the user that at least one negative number was created.

Mathematically:

New price = mean price within that half-hour + difference of old price from mean * user specified factor, if result is more than zero, or zero if not. See Equation 2.

$$P_{new} = \overline{P} + \left(P_{old} - \overline{P}\right) \cdot \lambda \quad \text{for} \quad \overline{P} + \left(P_{old} - \overline{P}\right) \cdot \lambda > 0$$

$$P_{new} = 0 \quad \text{for} \quad \overline{P} + \left(P_{old} - \overline{P}\right) \cdot \lambda \leq 0$$

Equation 2 Price 'volatility' transformation using factor λ

There are a number of advantages to this approach:

- The effect is relatively obvious and comprehensible to the analyst.
- Off-peak prices are moved by less significant amounts whilst Peak prices are moved a significant degree, approximately reflecting empirical behaviour since the spread of off-peak prices is significantly less than the spread of peak prices. Refer back to Figure 11.
- The analyst does need not be concerned with where the peak prices occur within a forecast and needs only to specify one simple factor. It is therefore quick to use.
- The formula prevents prices becoming negative. This does introduce an amount of distortion in the volatility transformation, but the trade-off was considered worthwhile since negative prices are meaningless.

This is just a first approximation as to what would really happen if peak price volatility were to change. However, at the very least, intuition alone does suggest that this technique succeeds in allowing the analyst to explore the effect of different levels of volatility in prices, and hence higher peaks on contract performance.

One alternative was considered. This alternative method would allow the analyst to increase values between specified dates and within specified half-hours by a certain amount, either by an offset or by a factor. However, this was rejected as it was considered much more complicated to specify and would require the analyst to determine where the peak prices were in a forecast.

More work is recommended to test the success of this technique and to examine other possibilities.

8.5 Tariff Structure Editor - Changing Tariff Structures

The flexibility provided by the *ESIPRAS* environment might lead an analyst into ignoring an important issue. As discussed in section 4.6.1.4, much research has been carried out into examining customer response to tariff structures. *ESIPRAS* allows the user to specify a wide range of different tariff structures for price calculation. An analyst might be tempted to quote prices calculated for a number of different tariff systems for a single customer forecast. In the research on customer demand, it has been shown that customers do indeed respond to price messages from tariff structures by adapting their demand. Therefore, to some extent, a sensible forecast should only be created with a specific tariff structure in mind. It would therefore be unsafe to assume that one could change a tariff structure in isolation to the forecast, in order to provide a customer with a different set of prices. This might introduce significant error into the calculation and the successful performance of such a contract with prices created from an unsuitable forecast could not be guaranteed.

At present, *ESIPRAS* is does not provide any facilities to adapt forecasts to changing tariff structures. Adding such facilities would not be a trivial task, and could represent an opportunity for further research.

8.6 The Price Calculator & Price Analyser

At present the *Price Calculator* and *Price Analyser* provide the user with a system to calculate only:

- break-even energy prices.
- use-of-system charges (in the case of the *Price Calculator*).
- a basic administration charge, based on the length of a contract.
- a margin.

Users might feel that this is restrictive. Improvements to these tools might include:

- Allowing the user to specify a fixed, one-off administration charge.
- Incorporating use-of-system charges into the *Price Analyser* calculations. Designed primarily as a tool for analysing the performance of tariffs between any number of scenarios, incorporating use-of-system charges in this tool was not a high priority. It might, however, present a useful addition.

8.7 Contract Risk Evaluation

The last chapter includes an example of analysing the effect of a worst-case Pool scenario. This analysis requires a fair amount of work on the part of the user. To get a full picture of a contract's level of risk, it would be necessary to create at least three scenarios for a contract:

- 'Best' case
- Worst case
- Most likely case

It would be necessary to run each one through a separate pricing calculation. This could become extremely laborious, especially if the user is trying to compare a number of different customers. The system, therefore, might benefit from a facility that either:

- Created a number of scenarios automatically, using some user-specified boundaries, and ran them through the pricing calculation to create some automated sensitivity analysis.
- Queried the user, in a structured fashion, for specifications of the best, worst and most likely scenarios.

The need for such facilities might be lessened if the risk coefficients provided by the *Risk Statistics Screen* could be relied upon.

8.7.1 The Risk Coefficients in the Risk Statistics Screen

The use of Load Factor (LF) as a basic indicator of risk has been discussed in a previous section. However, the risk statistics screen presents a second risk coefficient. LF has at least a couple of limitations as a risk coefficient:

- The reliance on using a maximum demand value in the LF calculation. One high outlying demand period will cause LF to be underestimated. Therefore, a relatively low risk customer might be erroneously considered high risk if the customer only has one demand period in which, for whatever reason, his demand peaked unusually high for just a half-hour during the whole contract.
- The use of LF as a risk coefficient relies on the basic assumption that peaks in demand tend to coincide with peaks in Pool price. This is not true of all customers.

An alternative measure is included in *ESIPRAS*, and is called *Rho*. This measure, whose application has been devised and suggested by this author, calculates the coefficient of correlation[50] of customer demand forecasts with Pool price forecasts. The higher the correlation coefficient, the greater risk a customer might represent as a:

- High Coefficient of Correlation suggests that high demand coincides with high Pool price. This makes energy cost highly sensitive to changes in either variable from the forecasts. We also know that peak Pool prices are significantly more volatile than off-peak prices, and their co-incidence with high demand means that this volatility will have more effect on the overall energy cost uncertainty.
- Low Coefficient of Correlation suggests that high demand occurs away from high Pool price, so that energy cost is less sensitive to changes in the volatile peak pool price and changes in demand.

The usefulness of the demand-pool correlation measure is intuitively compelling. However, it certainly needs to be considered in more depth as a risk coefficient. Empirical studies are obviously essential before the analyst could use it with any authority. Also, the measure relies heavily on the accuracy of the forecasts. However, it does provide the analyst with further statistical insight and the Coefficient of Correlation is a well-understood and common statistical calculation. The author sees no harm in including the measure in *ESIPRAS* as long as the analyst is aware that its ability to predict risk has not yet been demonstrated.

As an example of the limitations of LF, and the possible benefits of a Pool-demand Coefficient of Correlation, consider the following:

A local council wishes to agree a contract with a Supplier to provide electricity for its street lighting system. The Supplier wishes to examine how risky this contract might be. Imagine that the system uses no electricity during the day and a considerable amount during the night. Thus, LF will be low since the profile will be quite volatile. Busy with many other contract requests, the Supplier carries out a quick analysis of the historical meter data supplied by the council. Basing their decision on LF alone, the Supplier rejects the contract on the basis that it is too risky for the amount of return that they would expect to receive. The council approaches another Supplier who decides to examine the data more closely. An analyst notes that the lighting system is switched on shortly after peak Pool prices have occurred. This means that the profile avoids the most volatile and expensive period of Pool price during the day. This is confirmed by the demand-Pool Coefficient of Correlation measure that turns out to be quite low, suggesting that the contract might be low risk. The Supplier is confident that they can achieve enough return on the contract that it can justify the risk associated with it, which in their opinion, is small compared to the typical contracts that they are used to.

8.7.2 The potential for developing and incorporating a risk-value model

The present system provides only two coefficients for statistical risk evaluation, neither of which takes account of the expected value of a contract, e.g. the expected profit from a contract, an important consideration as mentioned in a previous section. Additional work could be carried out to develop a risk-value model to combine the provided risk coefficients with the expected value of contracts and the risk preferences of the user. These risk preferences might specify:

- how much risk the Supplier was willing to accept
- how much return he would expect for a certain level of risk.

In this way, the system could rank the demand profiles in memory according to their desirability.

8.7.3 Other Risks

Presently, *ESIPRAS* does not take account of credit risk assessments within its presentation of risk. The ability of the customer to pay his Supplier and meet his contract obligations is also important in a risk assessment. There is a potential for the system to be enhanced to include credit risk assessments, but at present, its development has focussed attention on the risks associated with the fluctuating electricity price and the unpredictable nature of a customer's demand pattern.

8.8 The Graphing Screens

The graphing tool is one of the most flexible tools within *ESIPRAS*'s facilities. It allows the analyst to inspect the relationship between electricity price and customer demand forecasts. It provides the user with the ability to inspect average values over a range of sample days. It also allows the user to inspect the variation in values over a range of sample days. The user can identify periods in which values are more volatile than others and therefore those which might represent sources of risk to a contract. However, examining this level of detail within a demand profile or price forecast, brings the data under greater scrutiny, and puts even greater reliance on the accuracy of the source of the data. There is nothing to be gained in examining the volatility of customer profiles and price forecasts unless the analyst is confident that the forecasts are representative enough.

8.9 Software Robustness

ESIPRAS is a fairly robust system. However, as with most software systems, bugs and coding errors will surface during the software's lifetime. This will require some measures to be put in place to provide the necessary manpower and other resources to maintain the system.

8.10 Field Study

The effectiveness of *ESIPRAS* in improving a Supplier's business performance needs ultimately to be researched. It is outside of the scope of this project to analyse its performance in the work place. *ESIPRAS* offers a number of useful, custom designed tools, that empower an analyst by improving and increasing the amount of information which he has on each contract. If the system was to be further improved, it is possible that it would be developed on a more commercial basis with contracted Information Technology professionals. In that case, the Supplier might want to carry out a cost-benefit analysis of any future development.

Chapter 9 Conclusion

The introduction of the Electricity Act in 1989 was an attempt by Government to improve the efficiency of our Electricity Supply Industry. At the heart of the measures implemented by this Act was the Pool, as discussed in Chapter 3. The Pool was created in an attempt to form a market for electricity which forced parties wishing to trade to do so at a price which reflected the cost of its production, as well as the level of demand and supply. The rules governing its operation have been altered since its introduction in an attempt to improve its ability to generate sensible prices.

The Act represents the most sophisticated attempt so far to increase the efficiency of the ESI by ensuring that energy costs are more transparent than ever, ensuring that more cost messages are transmitted from upstream production through supply to downstream consumption. An example of an older, less sophisticated and more blunt attempt at this was the *Economy 7* system.

Now all players in the ESI have to consider the significantly time variable nature of electricity price.

UK electricity Suppliers selling to the English & Welsh market face significant risks with regard to this fluctuating price of electricity and the fluctuating demand from their customers. In the worst cases, Suppliers can make significant losses on Supply contracts. This might lead to poor financial performance or perhaps even business failure.

This possibility is increasing as the market in the UK is liberalised allowing customers to chose their own Supplier. Since there is little to differentiate each Supplier's service aside from price, this will bring them under great pressure to reduce them and thus reduce margins. Suppliers need to respond to these risks by developing better tools to help price and analyse the feasibility of contracts.

The *Electricity Sales Integrated Price & Risk Analysis System* (*ESIPRAS*) was developed in response to this need.

It provides a computer system which allows the user, probably a contract sales expert, to both price contracts and analyse contract risk so that the Supplier can decide whether the contract is worth pursuing. The author hopes the system will demonstrate its credentials as a useful DSS for the analysis of electricity contracts in England & Wales. Some field testing has been carried out to ensure that calculations it makes are correct and most bugs have been removed. However, only long-term use and maintenance of the software will see it reach its potential. One major benefit from the use of this system is that it encourages the Supplier to focus on the importance of good information as a basis for making decisions.

This thesis has described the creation of this software, through discussing the background of the Supply business, arguing a need for such a system and describing the design of the system in response to this need.

This thesis has contributed to knowledge in several areas.

Firstly, the author believes it describes a novel application of a Decision Support System.

Secondly, it has provided a survey of Risk in Electricity Supply. Little literature existed on the subject prior to this research. As far as the author is aware, then, this is the most comprehensive study to date of the sources of risk within the Supply industry and the methods that can be used to reduce it. The author has attempted neither to suggest strict, prescribed methods to tackle risk, nor compare the efficacy of each method. However, he has attempted to provide a base on which such research and discussion could be founded.

Thirdly, the thesis provides a novel description of how Suppliers price contracts. It describes the data that the Supplier uses to price contracts, how this data is derived and manipulated. It also identifies the compromises reached when little information is available. The author does not claim that this is exactly how every Supplier prices his contracts, but hopes that it is a general reflection.

Moreover, the thesis has also highlighted a major insight.

The author has proposed a new metric for comparing the relative risk of different contracts. Load Factor has historically been used as a guide for comparing contract risk. As discussed in the last Chapter, there are significant limitations with Load Factor as a basis for comparison. It relies on too little information and assumes that peak demand always coincides with peak price. This is not always the case for every customer. The author's improved metric is found by calculating the correlation of customer demand with Pool price. This uses more information from available data and does not assume correlation between demand and Pool price peaks.

However, though intuition suggests that this metric will be more useful to the sales analyst, its benefits have yet to be demonstrated. The author would like to encourage further research in this direction, which would require a thorough survey of customer contracts and their performance in order to analyse the ability of this metric to predict contract behaviour. This would be a significant piece of research.

It would be necessary to show a correlation, for a large number of contracts, between the forecast risk, as predicted by the metric, and the level of deviation from expected outcome.

One difficult aspect of this research would be the interpretation of results. It would be necessary to devise a method of normalising the results from each contract in order that they might be compared and combined in a sample set for the statistical evaluation of the metric's performance. For example, any profit or loss figure used to represent the performance of a contract might have to be scaled by total turnover in order for it to be compared with another contract of a different size. Only with a large normalised sample set would any sensible indication of the metric's usefulness emerge. Many other issues would have to be considered. For example, it would be necessary to take into account the variability of the quality and quantity of information used to calculate the metric in each case. The metric is likely to be more successful in predicting risk, where there is more accurate information available. In addition, certain external events might skew the results in some unexpected way. For example, if an analyst was comparing two supply contracts to customers within two different industries, changes in the business environment for just one of the customers might make direct comparison more difficult.

The metric provides only part of the information that a Supplier would take into account when deciding whether or not to pursue a contract. It provides an indication of the potential variability of contract performance. A Supplier might incorporate this metric into a larger risk model to make his decision. As discussed in Chapter 4, a good risk model must also consider the expected value of a contract's profit or loss, so that a sensible risk/return assessment can be made. Research into creating such a risk model would also be highly beneficial as would its inclusion into the DSS.

There is a case for improving the software in other ways. Through discussing the design of the software, the thesis hopes to have shown how the process of pricing contracts has been captured in the Decision Support System. The benefits of using a well-designed DSS are well documented. The author is confident to have demonstrated the employment of good programming techniques and user-interface design.

However, there are several areas, as discussed in the last chapter, where the functionality of *ESIPRAS* could be extended.

This includes the potential for the adoption of a database backend. The system could be linked to a database of customer information thereby improving the ease and speed of data retrieval. At the same time, this could help improve data integrity.

Improvements might be made to the tools used to explore 'what-if' scenarios of different Pool price volatilities. As discussed in the last chapter, more work could be carried out to examine the inter-relationship of Pool prices throughout the day. In particular, this work might examine, in more detail, how the distribution of off-peak prices changes when the volatility of peak prices changes. The tools could then be extended to incorporate the results of this research.

Other extensions to the functionality of *ESIPRAS* are discussed in Chapter 8.

However, the author believes that the *ESIPRAS* system, in its present form, provides a flexible framework in which the analyst can pursue typical decision goals, by exploring many scenarios of both Pool price and customer demand patterns. The analyst can build up a picture of a potential contract or contracts. In this way, the analyst becomes more informed and can act on the basis of better information.

As final note, author believes that the work described in this thesis forms a significant contribution to the area of Electricity Supply contract price and risk analysis within the UK.

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Appendix A - Spreadsheet format

The data within each of the spreadsheet files must be arranged in a standard way, in order for *ESIPRAS* to be able to find it and load it into its internal memory. *ESIPRAS* was designed so that it used what seemed to be the most popular cell arrangement that the Supplier was using for his files. These cell arrangements for demand files and for Pool price files are shown in Screen Image A.1 and Screen Image A.2 respectively. Any file that the analyst wishes to import must conform to these cell arrangements or *ESIPRAS* will not be able to import the data successfully without error.

Hospital

	A	B	C	D	E	F	G	H	I
1	Site name		Hospital						
2									
3									
4	Number of days		365						
5									
6									
7	01-Apr-96				138.48	139.42	138.48	138.48	138.48
8	02-Apr-96				134.71	131.89	133.77	130.95	131.89
9	03-Apr-96				128.12	126.23	125.29	126.23	127.18
10	04-Apr-96				129.06	129.06	130	129.06	130
11	05-Apr-96				126.23	127.18	127.18	124.35	124.35
12	06-Apr-96				124.35	124.35	122.47	122.47	121.52

Hospital

Screen Image A.1 Example of demand data cell arrangement

Psp9497

	A	B	C	D	E	F	G
1							
2							
3	Description :		PSP in £/MWh - 1994-97				
4	No of Days:		1096				
5							
6							
7	01-Apr-94		15.72	23.71016	22.94246	23.71016	23.71016
8	02-Apr-94		10.97	19.52714	18.24091	19.52714	19.52714
9	03-Apr-94		15.72	21.06936	32.71152	32.71152	21.06936
10	04-Apr-94		10.83	25.90389	21.79639	26.26927	26.26927
11	05-Apr-94		10.84	25.38742	49.42749	49.42749	48.89243
12	06-Apr-94		16.98	33.79818	53.76012	53.76012	53.76012
13	07-Apr-94		17.1	23.03584	42.34246	42.34246	34.55749

Chart1 A

Screen Image A.2 Example of Pool data cell arrangement

The important locations that must be adhered to for successful data import are:

- Site description/Pool table name, cells C1 and C3 respectively
- Number of days in spreadsheet data, cells C4 in both
- A column of dates, referring to each day represented by the data, starting in cell A7 in both, with the date increasing down the sheet, one day per row.
- An array of data, 48 cells by the number of days in the file. The data array must have no gaps and exist in one block. The array's top left corner must be at E7 for demand data and C7 for Pool price data. Each day of prices or demand data is represented by a row of 48 cells, horizontally adjacent to the date to which it refers. Each cell represents a data point for one half-hour. Adjacent days are in adjacent rows.

The data files must also be in Greenwich Mean Time (GMT) format. That is, there must be 48 data points per day, each one representing each half-hour in a GMT expressed day; i.e. the first half hour of the day begins at 00:00 GMT and the last half-hour begins at 23:30 GMT. The effects of this are discussed within the thesis.