DEMAND SIDE MANAGEMENT WITHIN A REGIONAL ELECTRICITY COMPANY

An Energy Services Approach to Industrial Sector Demand Side Management

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THESIS SUMMARY

The work presented in this thesis concerns itself with the application of Demand Side Management (DSM) by industrial subsector as applied to the UK electricity industry.

A review of the origins of DSM in the US and the relevance of experience gained to the UK electricity industry is made. Reviews are also made of the current status of the UK electricity industry, the regulatory system, and the potential role of DSM within the prevalent industry environment. A financial appraisal of DSM in respect of the distribution business of a Regional Electricity Company (REC) is also made. This financial appraisal highlights the economic viability of DSM within the context of the current UK electricity industry.

The background of the work presented above is then followed by the construction of a framework detailing the necessary requirements for expanding the commercial role of DSM to encompass benefits for the supply business of a REC. The derived framework is then applied, in part, to the UK ceramics manufacturing industry, and in full to the UK sanitaryware manufacturing industry.

The application of the framework to the UK sanitaryware manufacturing industry has required the undertaking of a unique first-order energy audit of every such manufacturing site within the UK. As such the audit has revealed previously unknown data on the timings and magnitude of electricity demand and consumption attributable to end-use manufacturing technologies and processes. The audit also served to reveal the disparity in the attitudes towards energy services, and thus by implication towards DSM, of manufacturers within the same Standard Industrial Classification (SIC) code.

In response to this anttempt is made to identify the underlying drivers which could cause this variation in attitude. A novel approach to the market segmentation of the companies within the UK ceramic manufacturing sector has been utilised to classify these companies in terms of their likelihood to participate in DSM programmes through the derived Energy Services approach.

The market segmentation technique, although requiring further development to progress from a research based concept, highlights the necessity to look beyond the purely energy based needs of manufacturing industries when considering the utilisation of the Energy Services approach to facilitate DSM programs.

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GLOSSARY OF TERMS

Ancillary Services	Services required by electricity consumers in addition to the consumption of electricity.
Availability	The level of MW declared to the Pool.
Capacity	The annual maximum full load output from a power station usually expressed in MW.
Capacity payment	The component of the Pool Purchase Price which is designed to provide an incentive for generating capacity to be made available.
CCGT	Combined cycle gas turbine - a generating plant in which a gas turbine power unit is combined with a heat recovery boiler and steam turbine to achieve efficiencies of around 50-55%.
CfD	Contracts for differences – financial contracts designed to reduce exposure to volatility in pool prices, which are typically entered into between a generator and a supplier.
CHP	Combined Heat and Power - a generating plant that produces steam or hot air for heating, as well as electricity.
Demand	The total electrical load on the system at any one time.
Demand side bidder	A supplier who has a site which will offer demand reduction.
DGES	The Director General of Electricity Supply – the independent regulator of the electricity supply industry, and Head of OFFER.
Direct supply	Electricity supplied directly from the generator to the final customer.
Distribution	The provision of a system enabling retail electricity to be delivered from a Grid supply point.
DuoS	Distribution Use of System – the charges made by a REC to its customers for use of its distribution network.
EFA	Electricity Forward Agreement - similar to a CfD, but traded through a broker.
ESIS	Energy Settlements and Information Systems Ltd - the part of NGC responsible for managing the Pool settlements.
F-Critical	Returns a value to show the likelihood of a correlation between a data set being by chance.
First tier supplier	A regional electricity company supplying customers in its own area.
Fossil Fuel Levy	A government levy to encourage the use of non-fossil fuels for generation.
Franchise market	The market in which customers are bound to their regional electricity company for their contract to supply electricity.
GRC	Generator registered capacity – the maximum full load capacity of a generating unit, as declared by the operator.

Grid	The national high voltage transmission network.
GSP	Grid supply point - the point where electricity is transferred from the National Grid transmission system to the regional electricity company's distribution system.
GWh	Gigawatt hour. One gigawatt equals 1,000 MW; one gigawatt-hour represents one hour of electricity consumption at a constant rate of 1 GW.
IRP	Integrated Resource Planning. Investment appraisal methodology that accounts for all internal and external (e.g. environmental) costs.
KVA	Kilovoltamperes - the product of the voltage applied to the circuit and the current in the circuit.
KW, kWh	Kilowatt - a unit of power, representing the rate at which energy is used or produced: one kilowatt-houepresents one hour of electricity consumption at a constant rate of 1 kW.
Kurtosis	Returns the Kurtosis of a data set. Kurtosis characterises the relative peakedness or flatness of a distribution compared to the normal distribution. Positive kurtosis indicates a relatively peaked distribution, negative relatively flat distribution.
LCP	Least Cost Planning. Accounting methodology which considers all options for a project outcome & chooses that with lowest overall cost.
Load factor (customer)	A percentage-based figure which relates the consumption in kWh to maximum demand kW during the 8760 hours in a year.
Load profile	A customer's pattern of electricity consumption over time.
LOLP	Loss of load probability – the probability of generating capacity being inadequate to supply demand in a particular half hour. LOLP is used in the calculation of capacity payments.
Losses	The loss of electricity that arises through it flowing along a wire, the difference between generation and demand.
Mean	Returns the numerical average of a sum of the arguments
Mid merit	Generating plant that is not run as base load capacity, and is only expected to run for part of the day or part of the year.
MW, MWh	Megawatt, megawatt hour – one megawatt equals 1,000 kW: one megawatt hour represents one hour of electricity consumption at a constant rate of 1 MW.
NFFO	Non Fossil Fuel Obligation in England & Wales - A government obligation on the RECs to purchase specified quantities of electricity from power stations that do not burn fossil fuels.
NGC	The National Grid Company plc.
Non-franchise market	The electricity market outside the current franchise demand limit - up to September 1998 this is a peak annual demand of over 100kW.

OFFER	The Office of Electricity Regulation, headed by the Director General of Electricity Supply (DGES), currently Professor Stephen Littlechild.
PES	A public electricity (or first tier) supplier in Great Britain, comprising the 12 regional electricity companies of England & Wales, ScottishPower and Hydro-Electric.
Pool	The wholesale market mechanism through which electricity is traded between generators and suppliers.
PPP	Pool purchase price - the half hourly varying price which forms the basis of payments to generators for sales of electricity through the Pool (£/MWh) = SMP + LOLP * (VLL – SMP).
PSP	Pool selling price - the half hourly variation of the price of electricity paid by suppliers to the Pool (£/MWh) = PPP + uplift.
R Square	Returns the degree of correlation between data sets. A value of 1 indicatres perfect correlation.
REC	Regional electricity company - eg Southern Electric.
Second tier supplier	An entity (other than a regional electricity company operating within its authorised area) that provides a supply of electricity to premises under a supply licence granted by OFFER.
Skewness	Returns the skewness of a distribution. Skewness characterises the degree of assymetry of a distribution around its mean.
SMP	System marginal price - the price of the highest flexible bid in the merit order required to meet expected demand for each half hour of the day (£/Mwh).
Supply	The provision of electrical energy to customers.
Supply contracts	Contracts for the retail sale of electricity.
Transmission Services	Charges levied by the NGC for the operation of its transmission system.
TuoS	Transmission Use of System – charges levied by NGC for use of the National Grid.
TWh	Terawatt hour. A terawatt is a unit of power equal to 1,000 gigawatts: one terawatt hour represents one hour of electricity consumption at a constant rate of 1 TWh.
Uplift	The difference between the PSP and PPP, which is intended to cover payments for reserve, constrained running, forecasting errors, ancillary services and marginal plant adjustments.
Use of System Charges	The charges paid by a second tier supplier for use of the National Grid Company's transmission system and the local regional electricity company's distribution network.

CHAPTER 1

INTRODUCTION

Transmission and Distribution Systems

Transmission can be defined as the bulk transfer of power by high-voltage links between main load centres. Distribution can be defined as the transfer of the power provided by transmission to end-use consumers by lower voltage networks.

Power stations generate electricity at between 11-25 kV. This voltage is then stepped-up by a transformer sub-station to the main transmission voltage of 275 - 400 kV. The *supergrid,* which operates in this voltage range, feeds into another sub-system of transformers and powerlines operating at a lower voltage range of 132 kV. In terms of generating station connections, the supergrid is mainly connected directly to the most efficient and reliable stations, with less efficient stations feeding into the transmission system at the lower voltage.

The 132 kV network in turn feeds into the more localised distribution systems, with voltage stepping-down to 33 kV, 11 kV, or 6.6 kV Ultimately the voltage is stepped-down to 415 V three-phase, providing 240 V per phase. Certain isolated areas of voltage levels, different to those outlined above, can be found. An example is the 66 kV London cable system.

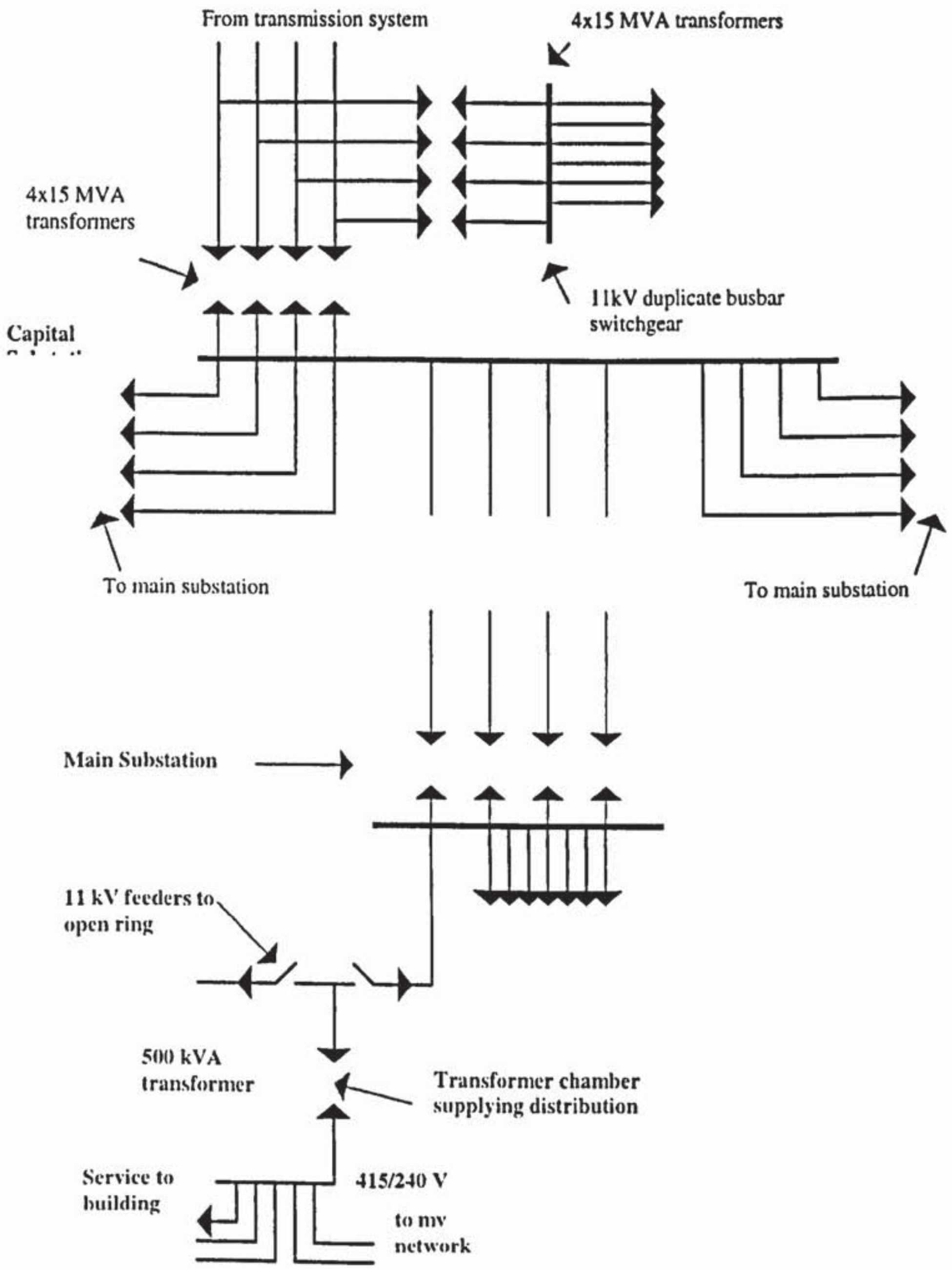

Figure 1.1 : Arrangement of a Typical Electricity Distribution Network (97)

Figure 1.1 provides a schematic of a typical distribution network. Distribution networks differ from transmission networks not only in voltage levels. The number of branches and sources within a distribution system is far greater than that in a transmission system. Typically, the distribution system will consist of a step-down (132 kV / 11 kV) on-load tap-changing transformer at a bulk supply point feeding a number of lines of a length which can be anything from one hundred metres up to a several kilometres. A series of step-down transformers (11 kV / 415 V) are spaced along the route and from these a three phase, four wire providing 240 V per phase is supplied to the end use consumer.

The local structure of the distribution system depends upon the geography and customer type. In rural areas radial feeders are often utilised which are typically overhead. In urban areas a well-defined low-voltage area or block is fed from the higher voltage network, these areas are often connected through fuses to neighboring and similar areas that are fed from different feeders in order to provide supply security. In such systems the network has essentially a topology of a loop nature. As most faults tend to be of a transient nature, auto-reclose circuit breakers are widely used. These open at times of system fault and then reclose after a short period. The process repeats three times if the fault persists.

It is often the case that two independent supplies are provided to the step-down transformer sub-station, in order to provide a continuing supply should one of the lines fail. The sub-stations themselves will contain two transformers for the same purpose. At any one time the maximum demand, either summed for the case of two transformers sharing load or the load on a single transformer, must be such that it does not exceed the maximum rated value of kVA for a single transformer. On this basis, the two transformers are seen to be operating in parallel, with the loss of one transformer not causing disastrous consequence for supply reliability and safety due to the fact that a single transformer can accommodate the combined loading. The rating of the transformer with the lowest kVA rating of a transformer pair is taken as the 'firm-rating' of the substation.

If the surplus capacity as described above were not in place then the overloading of a particular transformer would have serious implications for the security of supply. An identical pair of transformers, with one carrying 60 per cent of rated load and the other carrying 70 per cent of rated load may operate quite comfortably. However, the failure of either of these transformers could have serious consequences as the remaining operational transformer would be operating above its capacity rating by some thirty per cent. This could lead to one or more of the following consequences:

- The overloading of current could cause the thermal breakdown of insulating materials leading to potential arcing and other problems.

- The transformer could undergo thermal stressing, leading to a probable reduction in operating life even if the situation was recovered.

- There could be a lowering of voltage at supply points at the lower orders of the distribution/supply network. This could pose serious problems with the operation of some end-use equipment.

Thus the status quo provides distribution companies a guarantee that they are able to maintain the security of supply under fault conditions. This is essential due to the specific requirement to do so under regulatory contract (145).

Demand Side Management

Demand Side Management (DSM) can be defined as:

" A methodology through which a Regional Electricity Company (REC) can directly intervene in the customers' use of electricity in order to optimise the load curve"

(107)

This definition has been developed by EA Technology and is the definition deemed most appropriate for this thesis. Through adopting this definition the utilisation of tariff design in order to manipulate customer electricity usage has been disallowed. Tariff design in itself does not necessarily bring about any alteration of demand or consumption. If the tariff requires the purchase of new technology by the customer then it is difficult to reconcile tariff design with the concept of direct intervention. However, this definition does not seek to dismiss the role of tariffs in DSM objectives. If the Electricity Company were to offer whole or part funding of the technology, enabling the advantage of a new tariff, the company could be seen to be directly influencing the market for a technology and hence the customers' usage of electricity.

The definition does include load growth outside of peak demand, energy efficiency across all time periods, and reduction of peak load. It also includes load-shifting.

It is the proposal of this thesis that within the regulated electricity industry DSM can be applied through targeted Energy Services. This would provide a means with which to improve the profitability of Regional Electricity Companies (RECs). This can be illustrated through the optimisation of network assets in the distribution business, and the provision of energy services and long-term contracts in the supply business. Additionally, DSM can provide indirect benefits to the utility and society such as improving the quality of the environment and customer comfort and increased profitability or productivity.

Aims and Objectives

The aims of the thesis can be summarised as:

- To provide a framework for applying DSM by Industrial sub-sector, utilising an energy services approach. It is intended that the framework will be generic in its application across all industries. The framework will allow a methodical analysis to be made of any particular industry. This is done in terms of its ability to particpate in any given DSM program that aims to address specific network problems.

- To apply the framework to a specific industrial sub-sector, namely that of ceramics and, in particular, sanitaryware manufacturing. The application of the framework to a particular subsector will allow the methodology to be tested whilst providing an assessment of the potential within the sanitaryware sector for DSM programs.

- To investigate the ability to segment the industrial market for energy services / DSM with regards to customer strategy and operations. It is believed that it is inappropriate to solely focus upon the physical manufacturing processes within a particular subsector. Many factors influence the decision of a particular company to invest, or participate, in a DSM program. Investment decisions made by a particular company are influenced by several non-physical factors such as attitude to risk, management style, and company values. On this basis the targeting of DSM to a specific subsector may produce sub-optimal results in terms of customer participation. The segmentation of the market for DSM programs needs to consider non-physical factors in unison with the physical manufacturing process. On this basis it may be the case that companies from different industrial sectors form a market segment that is more, or less, inclined to participate in DSM programs.

- To provide an initial assessment of the potential for the creation of a computer based decision support system for the purpose of targeting DSM technologies within an industrial sector. The creation of a fully operational system is beyond the scope of this thesis. The work undertaken here is designed to provide an insight into the theoretical structure of the system. It is envisaged that the design of the system will provide an area for future work.

The aims and objectives are expanded upon in Chapters 8, 9, 10, and 11 respectively. The following pages set out the aims, objectives and contents of each Chapter.

Thesis Structure - Chapter Headings and Content

The UK Electricity Industry: Structure and Business Environment and the Role of DSM

The first six chapters address the origins of DSM in the US, and the relative costs and benefits that this utility planning strategy has derived A review is made of the UK electricity industry, and the potential role and contribution that DSM could make is developed together with a cost analysis of DSM in terms of the distribution business.

Chapter 2

DSM originated in the US in the early 1980's in response to a number of socio-economic concerns regarding energy usage and supply. However, the UK electricity industries and those of the US have very different backgrounds in terms of ownership, accountability, and operating environment. As such the assumption that DSM can be readily applied to the UK electricity industry on the strength of US successes is flawed. It has been found that certain technological, economic and marketing aspects of US DSM programs can be studied and utilised to the benefit of planning DSM programs within the UK. However, there are fundamental differences in regulation and industry structure which prohibit the ability of the UK electricity industry from being able to transfer complete DSM programs from the US into the UK.

Chapter 3

The differences between the US and UK electricity industries are highlighted through the review of the privatisation of the UK electricity industry in the late 1980's. The winners and losers of the UK electricity industry privatisation process are considered, along with an assessment of the changes within the industry in response to privatisation. The review reveals that structure of the privatised UK electricity industry has, to varying extents, simultaneously encouraged and inhibited the uptake of DSM as a strategic planning tool within the UK.

Chapter 4

The review of the privatisation process in Chapter 3 leads into a comparison of one of the most definitive differences between the two industries, the differences in regulation. Regulation of the UK electricity industry has brought about great benefits for customers in terms of lower prices and improved customer services. However, it has been found that UK regulation has also, in part, militated against the progressive uptake of DSM within the privatised arena.

Chapter 5

Chapter 5 brings together the considerations of the US experience of DSM and the UK electricity industry structure and operating environment. The result is an exploration of how DSM can be applied within the UK, and its relevance to each of the industry's players. Particular focus is placed upon the need to develop DSM through the Supply business under the ethos of energy services. It is suggested that energy services marketing provides the opportunity with which to address a number of concerns as to how DSM programs could be implemented and how utilities could gain from them.

Chapter 6

This chapter provides the reader with a simple illustration of how the economics of DSM are applied. The illustration uses an imaginary 33/11 kVA substation with two transformers approaching firm-capacity in order to demonstrate DSM. A number of scenarios concerning load growth are considered, and alternative DSM program solutions applied, in order to compare DSM with traditional supply-side investment. The results reveal the importance of accurately identifying the load growth rates on a seasonal and on a time-related basis when deciding upon whether to invest in the supply or demand side. Differences in the economic outcomes of the scenarios considered are stark, and serve to highlight the potential benefits of employing DSM as a planning tool.

Chapters 7 to 11 have been based upon the core research undertaken during the study. The research proposes the development of an energy services marketing framework as a means of assisting in the implementation of DSM within the UK electricity industry. The work relates primarily to research carried out in the ceramics manufacturing industry, focusing particularly on the ceramics sub-sector of sanitaryware manufacture.

Chapter 7

Chapter seven approaches the development of a framework for applying DSM by industrial sector through the application of energy services. The essential components and requirements of the energy services approach are defined, with reasons for their inclusion provided. A comparison of the benefits of the approach over the alternative of the 'blanket' industrial DSM technique is given, highlighting the usefulness of derived framework.

Chapter 8

This chapter utilises the framework set out in the previous chapter to provide an energy services solution to achieve DSM in the ceramics sector. Market analysis is provided on the sub-sectors of tiles, tableware and sanitaryware. The market analysis reveals the current market and economic strength of the sub-sectors, enabling electricity utilities to identify those customers which are most likely to be at threat from overseas competition and thus in need of advice or assistance in strict cost control. An overview is provided on the ceramics manufacturing process, providing brief details of common process stages and slight variations that exist between the subsectors.

Chapter 9

Chapter 9 applies the framework developed in Chapter 7 to the sanitaryware industry. The chapter provides an in-depth classification and analysis of electricity utilisation within the sanitaryware industry by process stage and end-use technology. The results have been achieved through a first-order energy audit of all UK sanitaryware manufacturers, supported by the on-site monitoring of electrical loads at one manufacturing site. The chapter reveals previously unknown data on the timing and magnitude of electricity demand of end-use equipment and process areas, and on the numbers and types of technologies in use across the sub-sector.

The information provided by the sub-sector survey is applied to the framework of chapter seven and the opportunities for providing energy services as a technique for implementing DSM are identified. The identified technologies for use within an energy services approach are described in terms of their load-shaping and economic impacts, as well as technical viability.

Chapter 10

This chapter provides a cost/benefit analysis of DSM within the sanitaryware sector. The chapter builds upon the knowledge of the sector gained through Chapter 9 and applies it to a specified network scenario requiring transformer substation replacement. The example focuses upon a manufacturer producing 10,000 pieces of ware per week.

The chapter aims to discover whether or not DSM is cost effectively viable within the sector under the scenario given and whether or not the sector can be seen as attractive for further DSM investment.

Chapter 11

The survey of the UK ceramics manufacturing industry revealed considerable variation in the attitudes of individual companies towards energy efficiency. These differences occurred at sector and sub-sector level despite common manufacturing process stages and accessibility to higher efficiency technologies.

It is suggested in this work that the route to DSM via energy services marketing is highly dependent upon being able to meets the energy needs of the customer as willing customer participation is essential. Chapter 11 addresses the market segmentation of the ceramics sector. The statistical technique of cluster analysis is utilised in order to determine whether or not customers within the same industrial sector would be likely to have the same needs from an energy services program. The analysis focuses not only on energy related requirements but also upon areas such as company strategy and operations. The results of the analysis show that investment in energy efficiency may not be driven solely by economic benefits but also by factors relating to company strategy and operations. The awareness of these factors should enable utilities to tailor energy services programs to the particular needs of several segments in what may, initially, have appeared to be a homogenous market.

Chapter 12

Chapter 12 can be viewed as a discussion of the findings of the research in a future context. The information that has been accumulated through the use of the framework developed in Chapter 7 has prompted a preliminary assessment of the potential for developing a database program. The program is to be utilised in conjunction with software held by the industrial sponsor of this research work.

Chapter 12 utilises the statistical technique of regression analysis in order to ascertain the feasibility of predicting process kW demand profiles for a particular site in relation to site and end-use technology throughput levels. It has been found that electrical loading can be predicted to a high degree of accuracy on fundamental technologies associated with the process stages of materials preparation, drying and firing. However, success of the technique in areas such as compressors and lighting is restricted by the variability of operation, and capacity installed, between sites.

It is envisaged that the ability to predict kW loading by process area, combined with the knowledge of end-use technologies, operating times, relevant DSM options and market segmentation, could be placed into a front-end database. Visual Basic has been used in order to provide the reader with an insight into the prospective format of the interface with the database. The program should be able to allow the user access to a range of DSM measures with which to address a particular load shaping objective. Once these measures are identified it is intended that 'DSM Assessment' software held by the industrial sponsor should be used to perform a cost-benefit analysis in order to ascertain the most cost effective and appropriate measure.

One of the prevailing problems with developing this database is yet to be resolved. This problem relates to the proposed separation of distribution and supply functions of Regional Electricity Companies. The proposals were made by the Director General for Electricity Supply at a time when this thesis was in its final stages. The impact of the proposed changes is discussed in Chapters 3 and 13.

CHAPTER 2

THE ORIGINS OF DEMAND SIDE MANAGEMENT (DSM)

Introduction

At present, within the UK, there would appear to be two major drivers behind the possible implementation of DSM programmes:

- The deferral of capital investment in network reinforcement associated with short-duration, high level, power demands. These are typically associated with the loads on transformer pairs within a substation exceeding firm capacity. These efforts fall under the term 'optimisation of assets'.

- Efforts to comply with regulatory drives for energy efficiency under the Standards of Performance (SOPs). Under the SOP scheme regional electricity companies are allocated funds, recovered from customers, to improve energy efficiency. Through the scheme, run by the Energy Saving Trust (EST), RECs have the potential to experiment with energy efficiency technologies that could be utilised within a DSM programme.

For reasons discussed in later chapters, DSM in the UK has focused upon the possible benefits for the distribution business in term of maximising the use of network assets, particularly those where maximum demand in main driver of reinforcement costs (11, 23, 53, 54, 69, 86).

Benefits to the supply business would appear to be rarely considered, primarily due to the current market in supply being very much focused on price competition and therefore limiting scope for energy services (128).

The industry environment in which DSM finds itself in the UK is starkly different to that of the United States where the concept of DSM originated. These differences are primarily seen in objective and regulation, both of which will be explored in this and the following chapters respectively.

The US experience of DSM

US utilities have been practicing DSM since the early 1980's (24, 57) as a means of reducing investment in generation capacity at a time when interest rates were high, making investment in capital intensive projects unattractive. This concept was enhanced by the fact that US electricity utilities operate as fully integrated businesses, operating along the chain from generation, to distribution, to supply. In addition to this, the oil crisis of the 1970's led to US government, and hence state regulators, looking at methods through which the country could minimise dependency upon fuel.

US regulation is carried out at state level, with electricity utility revenue calculated through a predetermined rate of return on their asset base (Chapter 4). During the 1980's and into the mid 1990's DSM expenditure was considered to be, by many state regulatory commissions, an element of the cost base of US electricity utilities (23). As such US utilities were guaranteed a return on the energy efficiency investments they made. In effect, investment in energy efficiency was treated as being suitable for inclusion in the utilities cost base in the same manner as more traditional supply side investment. This enabled regulators to make a direct intervention in utility spending programs in order to promote energy efficiency through DSM (9, 23, 27).

There are clear differences between the UK and US electricity industries:

- Regulation - done by state and therefore variable across the country in terms of policy and support for DSM.

- Rate of Return - Regulators applied a fixed and guaranteed rate of return on all justifiable utility expenditure. The allowable rate has in some states been increased for DSM programme spending. Allows greater freedom to explore potential costs and benefits of DSM.

- Government - Central Government influence on state regulators is strong, leaving regulators strongly influenced by federal policy.

- Investment Levels - Deferral of investment in generation plant leads to higher absolute levels of capital to spend on DSM programmes. This enables utilities greater freedom to explore with DSM programme costs and benefits.

- US electricity utilities are vertically integrated, providing greater scope for co-ordination between business functions in pursuit of the common goal. UK industry is now disintegrated to varying extents (Chapter 3).

These primary differences between the US and the UK electricity industries and their operating environments have led to the US pursuing DSM with comparatively greater vigor than the UK.

US Investment in DSM

Table 2.1 reveals expenditure at the ten US utilities identified as investing the largest sums of capital in DSM. Generation plant deferment is seen as the primary focus of DSM, with programs measured on a cost-benefit basis against the number of MW deferred. Table 2.1 shows the contribution made by DSM measures to reductions in peak demand and to total sales by a number of US utilities. In many cases the capacity deferment is substantial, exceeding 1000 MW. The US power industry invested US$550 million in capital expenditure in 1992, with another $2 billion in non-capital expenditure (60).

Utility	Generation (GWh/yr)	Revenue ($M)	1991 DSM MW Reduction	1991 DSM GWh Reduction	Cost $M	1991 DSM as % Peak	1991 DSM as % Sales	1991 DSM as % Revenue
PG&E Co.	80427	7378	700	620	150.4	4.9	0.8	2.4
SCE Co.	78643	7292	2358	585	107.4	14.1	0.7	1.5
CL&P Co.	26386	2276	260	811	81.6	6.1	3.1	3.3
CE Co. NY	39227	4910	161	266	76.6	1.7	0.7	1.6
FP&L Co.	74331	5159	1132	2625	72.0	8.0	3.5	1.4
FPC	29149	1719	998	408	58.6	16.8	1.4	3.4
NMPC	39371	2883	67	345	55.3	1.1	0.9	1.9
ME Co.	15985	1364	108	341	53.7	3.7	2.1	3.9
CP&L Co.	42771	2686	1318	4418	52.9	15.6	10.3	2.0

Table 2.1 : Top Ten Utilities in Terms of DSM Expenditure in 1991. (60)

Reasons for such expenditure on DSM have been put forward by many commentators on US DSM (60, 80), and include :

- They are cost-effective
- They increase customer satisfaction
- They provide environmental benefits
- They are required/encouraged by regulatory bodies

F.Sioshansi (80) provides a further list of reasons:

- DSM is strongly encouraged through Integrated Resource Planning (IRP) requirements (Regulators, under Rate of Return regulation, require all internal and external costs and benefits of alternative investment options to be accounted for).

- DSM has become the politically correct thing to do, being strongly endorsed by environmental movements. Traditional supply side investments are increasingly out of favour.

- DSM programmes, if properly planned, implemented and maintained, could increase customer satisfaction/welfare, and could be cost-effective - particularly relative to new resource options.

- Utilities in some jurisdiction can actually derive increased profit by investing in DSM.

The final point in the above list refers to some state regulatory bodies allowing an increased rate of return on DSM expenditure over that allowed on supply side investment. This facet has come under considerable criticism from some commentators, leading to the suggestion that some utilities may have been enticed into overstating DSM programme savings and benefits (60).

DSM in a Changing Industry Environment

The US electricity industry is currently undergoing a programme of change, moving away from the traditionally integrated and monopolistic state utility to a model of competition similar to that proposed in the UK (16). Although the exact nature of these changes are not explored in this thesis, being deemed beyond its scope, the impacts of a competitive environment on DSM have been the subject of some speculation.

A study in 1996 of 37 electric utilities across the US (representing 51.9 percent of total US expenditure on DSM) revealed that between 1992 and 1994 expenditure on DSM programmes grew at a median annual rate of 16 percent (165). For 1994-98 these utilities have forecast an annual decline of 3 percent in total DSM expenditure. This downturn in DSM expenditure has been directly linked to the onset of competition in generation and supply of electricity.

US commentators have suggested that state regulatory funded DSM will lead to considerable changes in future DSM planning (166):

- DSM programmes will become more cost-effective and service orientated.

- A movement away from rebates and direct installation of DSM measures and into the recovery of programme costs from participants. This will include financing packages, shared savings programmes, and market transformation activities.

- A shift in emphasis from residential DSM to industrial and commercial DSM.

In addition to the above, it is considered that DSM will find most favour in future where the utility fears losing customers to competition, needs to avoid investment associated with peak demand, and attaches substantial importance to state regulations on IRP. DSM, it is stated, will decline if the utility fears losing customers to self-generation, or competitors, and experiences excess capacity (165).

Indeed, an article in Public Utilities Fortnightly, Feb 15 1996 entitled 'Price Caps & Competition Conspire Against DSM' reveals that the Maine Public Utilities Commission expects DSM investment to reduce dramatically in a competitive market. This is suggested in response to the fact that the proposed five year regulatory review will increase regulatory lag and reduce incentives to increase profit through load building exercises. This is most likely to occur if the present system of rate-of-return regulation is maintained, and a utility's customers choose to switch supplier, leading to stranded investments within a regulatory review period. It is in light of this that Idaho Public Utilities Commission has shifted its policy on DSM, allowing Idaho Power Co. to terminate industrial DSM programmes due to concerns over stranded assets and lost investment in customers who switch suppliers in a competitive market (165).

Despite the increasingly apparent differences in market drivers and industry environment, it is still possible to transfer knowledge and experiences of DSM programmes on a technical, rather than cost, basis to what could be expected of UK DSM programmes. This is now explored.

Success of DSM Projects in the US

A study in 1993 by Jordan and Nadel (60) focused upon the experiences of over seventy US utilities with industrial DSM programmes. Table 2.2 summarises their findings. Custom measures are defined as those measures implemented on a factory-by-factory basis. Prescriptive measures are defined as those where the DSM technology was considered to be generic e.g. high efficiency motors and lighting. A successful program was defined as a program which achieved a participation rate of greater than 20%.

	Participation Rate (%)	Savings (% of 1989 industrial sales)	Number of Programmes in Category
All Programmes	9.4 %	0.65	31
Prescriptive - motors	n/a	0.16	6
Prescriptive - others	n/a	0.06	3
Custom	8.0 %	1.34	16
Custom & Prescriptive	14.2 %	0.31	6
'Successful' Programs	20.3 %	1.33	12

Table 2.2 : DSM Programmes in Operation in 1993 (60)

Table 2.2 reveals that a relatively small number of the DSM programs surveyed could be classed as 'successful'. Over 75 % of the total number of programmes had participation rates of less than 10 %, accounting for savings of less than 1% of total industrial sales. Many of these programmes were of a prescriptive nature, emphasising lighting and motor improvements, with very few focusing upon actual production improvements within a manufacturing process.

An earlier study by Nadel in 1992 (61) concluded that industrial DSM programmes were generally more cost effective than DSM programmes in both the commercial and the domestic sectors. Nadel found that domestic measures cost an average of $0.07, with those in the commercial sector costing an average of $0.05. In reference to Table 2.2 Nadel found that the cost per kWh ranged from $0.003 - $0.045, averaging $0.019. Table 2.3 provides examples of some of the DSM programmes utilised by various US utilities.

Utility	Program	Participation Rate	Savings as a % Industrial Sales	Utility Costs ($/kWh)
BC Hydro	Compressed Air	60 %	0.2 %	$0.012
BC Hydro	Motors	60 %	0.3%	$0.016
Clark PUD	Industrial Lighting	10 %	not available	$0.035
Niagara Mohawk	Motors and Drives	3 %	0.1 %	$0.015
WEP Co	Smart Money for Business	49 %	2.5 %	$0.021
BPA	Con/Mod Program	100 %	2.5 %	$0.006
BPA	Energy Savings Plan	26 %	0.8 %	$0.007
Puget Power	Industrial Conservation Program	5 %	2.0%	$0.026
UI	Energy Blueprint	60 %	0.1 %	$0.035

Table 2.3 : DSM Programs, Savings and Costs (61).

The study suggests that some DSM measures meet with greater success than others. Retrofitting higher efficiency lighting, widely touted as a DSM measure, is seen to be one of the more ineffective measures. Retrofitting industrial lighting is seen to have the highest cost on a kWh basis and a very low participation rate of 10 %. In comparison, those DSM programs, which apply less prescriptive measures and consider the operations of the business and related energy needs meet with more success. BPA and WEP Co have achieved high participation levels and lower costs per kWh through this approach.

Table 2.3 suggests that one of the major reasons for the differences in DSM program success is the selected method of approaching industrial customers with DSM. The major focus of any program of diversification away from being an energy supplier to an energy services provider, facilitating DSM, is one of customer needs. It is obvious that all factories require lighting. However, lighting is a relatively basic need of industrial customers when considering the production process as a whole. A more focused approach would develop a DSM program that addressed the prevalent needs of the company such as increased productivity and/or product quality. This facet is explored further in chapter seven.

However, the above may be too simplistic. Table 2.3 does reveal that certain prescriptive measures do meet with success in terms of cost and participation levels, such as compressors and motors programmes, whilst some customised approaches do the reverse. As such, it may be that there is no ideal way of approaching the promotion and implementation of DSM programmes. It is likely to be the case that underlying needs and outlooks of customers will show a spectrum of differences. On this basis prescriptive measures may provide an introduction to energy services programmes for some industrial customers, whilst for others the approach may achieve the reverse.

The concept of customer needs when considering investment in DSM is explored and developed in chapter ten. Customer needs in this concept relate to those of cost-control, investment appraisal, working environment and maitenance of end-use equipment.

Costs of DSM

Costs associated with DSM as carried out in the US are seen to consist of administration, marketing, evaluation, reporting and rebates/incentives (44). As costs are (or were) spread across the utilities entire customer base then there arises a situation of both winners and losers. This occurs as average electricity rates increase whilst consumption goes down for participants, whilst consumption remains the same or increases for non-participants as average electricity rates rise (44).

However, the proponents of DSM justify such imbalances through the highlighting of external benefits such as reduced pollution, from which society as a whole can benefit (35). Additionally, it is argued that average electricity rates will decrease for all in the long run as demand side proves less expensive than supply side investment (45). Ultimately views come down to whether DSM is justifiable in terms of social good over customer sovereignty.

This debate has been seen to spill over into the UK. The Director of the Office of Gas Regulation (OFGAS), Ms C.Spottiswoode, refused to allow gas consumers to be levied by the Energy Saving Trust. The levy was suggested as a means of sponsoring energy efficiency for societal good but was dismissed as cross-subsidisation by the taxation of some customers for the benefit of others. In contrast, the electricity regulator, Prof S.Littlechild, agreed to the levy and its proposed benefits and goals.

An area of on-going debate within the US is whether or not DSM is cost-effective. This is usually seen through debate on *negawatts* whereby savings are calculated on the basis of energy not supplied allocated a p/kWh value. A survey by P.Joskow and D.Marron (44) concluded:

- No one really knows how cost-effective a negawatt is due to the differences in cost accounting by different entities - although there was a general consensus which is that program costs may have been understated.

- The p/kWh reported by utilities can vary by an order of magnitude depending upon the market segment targeted and the type of DSM program utilised.

More detailed allegations surrounding the actual understatement of costs and overstatement of kWh savings can be found in the relevant report (44). However, areas of cost appraisal singled out for scrutiny included utilities being too ready to rely on pre-programme engineering estimates of savings, overstatements of DSM technology lifespans, and a failure to account for those in the market who would have adopted the proposed measure regardless of programme incentives i.e. *free-riders*. One of the main points of the report was that commercial and industrial DSM programmes are continually more cost-effective than those targeted on the residential sector. Industrial/commercial savings achieved an average cost of 5.1 cents per kWh, compared with 8.1 cents per kWh in the residential sector.

Utility Incentives for DSM

US utilities are allowed to obtain returns on DSM investment through several mechanisms, as set by the relevant regulatory body. Table 2.4 displays the revenue recovery mechanisms operating in the US as at 1994.

Mechanism	Method of Revenue Recovery
ROE adjustment	Adjusting allowed returns on equity to reward or penalise utilities for relative progress in developing DSM potentials (6 jurisdictions as at May 1994).
DSM mark up	A fixed mark up on DSM expenditures (%). (2 jurisdictions as at May 1994).
Performance Premium:	A 'bounty' per unit, kW and kWh, of resource saved in excess of a nominal goal. (5 jurisdictions as at May 1994).
Rate Base Premium	A return premium for rate based DSM investments. A rate above that payable on supply side investments. (5 jurisdictions as at May 1994).
Shared Savings	Allowing the utility to retain for its shareholders a predetermined portion of any savings realised throughout the use of DSM. (15 jurisdictions as at May 1994).

Table 2.4 : DSM Recovery Mechanisms Operating in Various US States as at 1994 (25).

The range of recovery mechanisms detailed in Table 2.4 all have their proponents and detractors and fierce debates on the costs and benefits of DSM have been a feature of the US electricity industry since the early 1990's.

A survey (60) examining the correlation between investment in DSM and the incentives of doing so unsurprisingly revealed that the higher the return available from DSM, the higher the utility investment. The survey revealed that, on average, a 15 per cent return on investment was available to US utilities pursuing DSM. The extremes of this average were as low as 1 per cent and as high as 75 per cent. These findings lent further weight to the claims of some commentators that the level of incentives available for DSM investment could lead some utilities into overstating DSM costs and requirements, thus leading to a neglect of more cost-effective supply side investment.

In a review article by S.Nadel (60), lessons learnt from the US experiences of DSM to 1994 could be summarised as:

- DSM incentives have been generally effective in motivating investment in DSM by utilities.
- Much has been accomplished in terms of energy and capacity savings.
- There has been a regulatory zeal to push DSM and IRP over the short term, leading to serious concerns over the costs and benefits of DSM investment.

The debate on DSM within the US electricity industry continues and, in response to changing market conditions such as the introduction of competition, is changing focus. Many commentators now accept that DSM as it was, mandated by state regulatory body and subject to inflated returns, will not survive in a competitive market (165). As such DSM will find favour in cases where realistic returns are available and fit with IRP objectives, along with the desire of utilities to retain customers and optimise the utilisation of assets.

US DSM : Lessons for the UK Electricity Industry

The experiences of the US with regards to DSM are built upon significant differences in terms of industry structure and regulatory process. The US utilities have, until the recent onset of competition, always enjoyed a monopolistic position within the state that they served. These utilities were vertically integrated and thus able to maximise planning value to the business, making investment relatively risk free, through DSM activities. This was, in part, strengthened by the regulatory objectives at state and federal levels being particularly enthusiastic towards DSM, offering returns on investment at higher levels than supply side measures.

There can be little doubt that the higher rate of return attracted by demand side investment, and the mechanisms of revenue recovery offered by state regulators, distorted the market for DSM. DSM investment has been relatively high in the US and has only recently begun to be tempered by the prospect of a competitive electricity market. This new market is similar to that of the UK and, with the verdict on the future success and practicality of DSM being in question, many utilities are now significantly scaling back DSM investment.

Despite the turndown in investment in DSM by the US as a competitive electricity market emerges there are valuable lessons for the UK. These lessons will need to be considered whether DSM is pursued in earnest at a business or political level. The technical and social aspects of this are highlighted below:

- Cross-Subsidisation: this would become particularly apparent if a levy were applied to all customers as a means of collecting revenue for DSM investment. The issue relates to residential and commercial customers but particularly to industrial customers. For example, is it correct for a utility to invest in DSM technology at a relatively inefficient industrial site whilst not doing so at a rival site in the same locality. Such issues are likely to be fiercely contested if a 'DSM levy' is applied in the UK.

- Incentives to Invest in DSM: it is acknowledged in the US that utilities do require a form of incentive, above that offered by supply side investment, in order to invest in DSM. What is necessary is to find the right balance to persuade utilities to move from relatively low risk, and familiar, supply side investment into the unknown of DSM. However, excessive returns could push the problem the other way, neglecting cost-effective supply side investment.

- Programme Monitoring: The verification and monitoring of savings and performance of DSM technologies is an essential part of evaluating cost-effectiveness. Ground rules need to be established and decisions made as to whether or not savings verification should be an independent business.

- Industrial prescriptive DSM programs are not as effective as customised programs in terms of participation rates or absolute savings.

- Industrial and commercial DSM programs tend to be more cost-effective than domestic programs.

- Longevity of Programmes: Further research is needed into the persistence of energy savings devices. This needs to take account of engineering estimates of lifespans and also changes in customer behaviour over time.

All of the above relate to problem areas of DSM programmes that are applicable to all utilities, regardless of whether or not the electricity industry in question is in a monopolistic or a competitive environment.

The US, now embarking on a path towards a competitive electricity market, has yet to find where DSM fits into the planning horizons of utilities. Whilst this uncertainty has not led to the collapse of DSM overnight, there are clear signs that both utilities and regulators are downsizing DSM investment. This occurs as both rethink the future costs and benefits of DSM in the context of the new market. Whether DSM will continue to hold as prominent a role in the future remains to be seen.

CHAPTER 3

PRIVATISATION OF THE UK ELECTRICITY INDUSTRY

Introduction

Over the last twenty years the UK has experienced dramatic changes in the running of the energy sector as a whole. Fundamental fuel industries have allegedly undergone rapid and total transformation from previously onerous bureaucratic public corporations, nationally owned for the good of the entire nation, into private sector firms striving to deliver profits to shareholders (88, 93, 150, 152, 159). This massive program of privatisation featured as a major policy on the political agenda of the Conservative Government elected in 1979.

Prior to the rolling programme of Privatisation introduced by the Conservative government the energy industries were held in the public sector. This policy was started in 1945 by the then Labour Government in the belief that the large profits available from these monopoly industries could be used for the good of the UK economy as and where required.

It has been claimed that under nationalisation the approach of cost plus funding encouraged the CEGB to spend excessively on network and generation assets. In effect the CEGB could readily be accused of over engineering the electricity industry. The benefits of this arrived in the form of a high quality electricity infrastructure with superior reliability. However, such a comprehensive system came at a correspondingly high level of cost (23, 92).

At the time of writing, July 1998, the UK's gas, electricity, telecommunications, oil, railroads, and water assets have been offered to the public through privatisation. The process of privatising the UK electricity is described in the following pages.

Privatisation of the Electricity Industry in England and Wales

Prior to privatising the CEGB the Conservative government of 1988 waited for the results of a review of the previous privatisations of both British Gas and British Telecom. As a result of this review (135) the government came to the conclusion that it would be preferable to move away from the concept of selling a public monopoly into a private monopoly. Instead it decided to break up the Central Electricity Generating Board (CEGB) and Regional Electricity Boards into component parts. As such, the contestable parts of the business, namely generation and supply, could be opened up to competition (135).

The reason for this relatively radical plan of privatisation was the over-riding principal of the power of the competitive market to reduce inefficiencies thought to be inherent within the nationalised industry. As such the privatisation of the electricity industry is the largest program that has occurred to date, undertaken with the intention of creating a fully competitive market for electricity supply starting in the over 1MW demand market in April 1990. The intention being that a fully competitive market would be available to all customers by 1998.

__A Restructured Industry__

In order to achieve its objectives the Conservative government separated the industry into its component parts of generation, transmission, distribution, and supply. Unlike in previous privatisations, such as gas, this restructuring had the effect of removing non-essential monopoly power, liberalising areas that could be subjected to the power of market forces in order to increase efficiency and reduce prices. Any areas of the business that could not be opened up to competition due to their naturally monopolistic nature, namely distribution and transmission, were to be regulated.

A regulatory body responsible for overseeing the privatisation was established, known as the Office of Electricity Regulation (OFFER), headed by the Director General of Electricity Supply (DGES). The primary duties of the regulatory body are to prevent the abuse of monopoly power, promote competition where applicable, and to protect customers from discriminatory pricing whilst maintaining the on-going viability of the industry (135). The 1989 White Paper formally set out these duties as:

1. to secure that all reasonable demands for electricity are satisfied.
2. to secure that licence holders are able to finance the activities which they are authorised by their licences to carry out.
3. to promote competition in the generation and supply of electricity.

In addition to these primary duties there are secondary duties, namely:

1. to protect the interests of consumers
2. to promote energy efficiency and economy
3. to promote research and development
4. to protect the public from danger
5. to secure the establishment of health and safety procedures

(135)

The DGES is viewed as being independent of the government by whom he/she may be appointed. As such the position reflected the Conservative government's desire to keep privatised industries at arms-length. However, it is widely recognised that the Secretary of State shares the powers of the DGES and, on major issues, will often become involved with a view to reaching a final decision (151). This was seen in the proposed merger of Midlands Electricity plc and Powergen plc in 1996. It was Powergen's intention to achieve vertical integration through the purchase of a REC, namely Midlands Electricity plc. However despite the Monopolies and Merger Commission agreeing to the purchase, subject to certain conditions, the Government blocked the deal on the grounds that it considered there to be too little competition in generation (156). As such Government felt that Powergen could obtain an unfair advantage over other generators by virtue of integration into distribution and supply.

The REC Businesses

The previous Area Electricity Boards were renamed as Regional Electricity Companies (RECs) and granted licences for the services that they are required to provide. The services are primarily classed into the provision of the distribution and supply of electricity. At present there are twelve such RECs within England and Wales, with geographical boundaries matching those of the previous Area Boards. Much of the Distribution business of the RECs is regulated through price-cap control, with exceptions applied to certain areas of operation (150).

Distribution

Distribution represents a natural monopoly and is heavily regulated. This regulation is achieved through an average revenue allowance per kWh distributed. This average revenue allowance is made up of a basket of tariffs that are subjected to a price cap of RPI-X. The tariff baskets vary from REC to REC, reflecting the differences in the cost of serving a particular end-mix of customers and the state of assets at vesting. The baskets are classed as:

- LV1 - units sold to customers connected at low voltage at a higher day or peak time price.
- LV2 - units sold to customers at low voltage at a lower night or off-peak price.
- LV3 - units sold to customers connected at low voltage at uniform prices such as the standard domestic tariff.
- HV - units sold to customers connected at high voltage.

Source: OFFER 1994 Distribution Price Proposals (150)

Due to the variations in REC allowances a kWh distributed at LV1 can range from 1.6131 p/kWh in East Midlands to 2.4442 p/kWh in SWALEC, and a HV from 0.4584 in Eastern to 0.7272 in SWALEC as at 1994 (150). Further details on the regulation of the UK electricity industry will be discussed in Chapter 4.

Supply

Supply is a partial monopoly as competition is slowly phased in up to September 1998 when it is proposed that all customers will be able to select a supplier of their choice. At present only those customers with a demand in excess of 100kW are able to choose suppliers in the open market. As such the market below this level is deemed a franchise market and is thus subjected to price control via regulation. In order to qualify for the competitive market the site in question must have a recorded demand exceeding the threshold rating (100kW) on three occasions in three separate months.

Supply is regulated in the below 100kW market via an average price cap on revenue per kWh. Within the franchise market the supply business is able to pass through its costs of generation, transmission, distribution and the NFFO by virtue of the 'y' factor. The NFFO is set, at present, at 2.2 per cent.

$$P = RPI+Y(+ \text{ or } -)X$$

P = Revenue per kWh

Y = Pass through

X = Adjustment factor

(152)

In addition to the above price cap there is a volume driver on the supply business that relates 25% of revenue to kWh sold and 75% of revenue to customer numbers.

The regulator, upon comparison of REC costs which included projections of customer numbers and sales, acknowledged that due to geographical boundaries and variations in customer mix some RECs had different base costs. As such sums of revenue were classed as constant terms, to which the price cap would not apply. The sums range from £10m for Midlands Electricity up to £16m for London Electricity (152). any revenue gained above these sums is subjected to the stipulated price-cap.

At 1994 the X factor in Supply was set at minus 2% for all companies, rising from 0% at vesting, in reflection of anticipated cost reductions and increased efficiencies within the Supply business. As such the 1994 price proposals set, in 1991/92 prices, a constant term of £15.84 per customer and 0.0924 p/kWh, with a view to a 1% profit margin on turnover. This tightening of the X factor has served to fuel arguments that the utilities were sold off too cheaply at vesting (23).

Transmission

The bulk transmission system was renamed as the National Grid Company (NGC), initially jointly owned by each of the 12 RECs, who were required to sell the business in 1996. The transmission of electricity from the power stations and into the distribution networks of the RECs is a monopoly operation and, as such, the NGC is also regulated by OFFER. The formula is based upon that used for the REC distribution business, with X set at -3 in 1992/93 taking effect from 1993 until 1997. The 1997/98 review set a target of –4 for X until 2001(149). Within the first year this led to a twenty per cent fall in the income associated with NGC's regulated business. However, again a privatised part of the UK electricity industry managed to trim costs and the financial institutions in the city responded with several buy recommendations for NGC stock (The Times 3/6/98).

The NGC is unable to obtain a second tier supply licence and is not allowed to generate electricity. On this basis it was forced to divest its holding of pumped storage plant in Wales, bought by Mission Energy of the US in 1995/6. The NGC may not discriminate unjustly between suppliers, and its charges are based on access (grid entry and exit), and use of system for infrastructure and service.

The charging structure, which is common to all suppliers, has been set to encourage new stations in areas of low generation such as the South West. In these areas access charges are expected to be minimal, even negative, to new generation units. Thus pricing contracts will be influenced by which supplier has managed to contract access to the nearest generation to a particular customer, on the basis that it is more expensive to transport electricity from North to South and East to West. A further charge levied by NGC is a capacity charge referred to as 'Triads'. Triads are the three half-hours of highest national demand for electricity during the winter months from the beginning of November to the end of February, and they must be separated by at least ten days. RECs attempt to forecast Triad periods in order to provide warning to customers to attempt to reduce electricity demand and hence electricity costs.

Generation

The generation sector of the CEGB was split into two companies, known as Powergen and National Power and allocated 30% and 70% respectively of the UK's power stations with a mix of fuel sources. The uneven split in generation was defended on the grounds that National Power would have to accommodate the nuclear stations at a later date. These nuclear power stations, under Nuclear Electric, were initially held back from the Privatisation process, primarily due to public concern over safety issues and the economic viability of certain plants. However, it has now been decided that some of the older Magnox stations are to remain under state control, with others being sold to BNFL ltd. The newer PWR and AGR stations were delivered into the private sector in September 1996 under the trading name of British Energy plc. British Energy plc consists of two operating subsidiaries, namely Nuclear

Electric Ltd. and Scottish Nuclear Ltd. The fact that only two major generators were created at privatisation has been a major source of criticism of the governments failure to go far enough in pursuit of competition (138).

Generators are entitled to sell electricity through the obtainment of a second-tier supply licence, as Powergen, National Power and British Energy have done, although they are restricted to only 25% of the market by volume (164). On a similar footing, RECs are allowed to generate 15% of their electricity requirements (150). Upon privatisation most RECs wasted little time in re-integrating vertically into generation through projects to build Combined Cycle Gas Turbine (CCGT) stations. Reasons suggested for this rapid investment in CCGT included the RECs desires to protect themselves from the market power of the two major generators and to break into unregulated areas of business (88).

New entrants into generation (Table 3.1), and increased availability levels of nuclear power have steadily eroded the market share of the two major generators.

	1989/90 (%)	1995/96 (%)	1996/97 (%)	1997/98 (%)
National Power	48	31.5	24.1	21.0
Powergen	30	23.1	21.5	19.6
Nuclear Electric		22.5	17.3	16.7
Magnox Electric		0.0	6.9	7.5
Eastern		1.3	6.6	9.7
New Entrants - CCGT		10.4	12.2	14.4
New Entrants - Other		1.2	1.3	0.9
First Hydro		0.7	0.8	0.9
French Interconnector		5.7	5.8	5.7
Scottish Interconnector		3.6	3.5	3.5
Total		100	100	100

Table 3.1 : Market Share of UK Generators by Output (126)

However, in 1996 OFFER, concerned about their ability to set prices in the wholesale pool electricity market, obtained the agreement of both Powergen and National Power, under threat of referral to the MMC, to dispose of 40% of their generation assets. This was duly done in 1996 when Eastern Electricity (Hanson) bought 4000MW and 2000MW of National Power and Powergen oil and coal fired plant respectively.

The Electricity (Unified) Pool

Under the old CEGB system power stations were called upon in a merit order in order to satisfy the demands for electricity. A certain level of electricity demand, known as base load, is constant and as such is relatively inexpensive. However, the demand for electricity is not constant and is characterised by peaks and troughs, which in turn requires generation plant to be able to react flexibly in terms of output. The standby capacity required to meet these variations in demand, both by season and time of day, is very costly. Thus the merit order, reflecting the costs of starting up and shutting down generation stations, enabled the CEGB to attempt to control the costs of generation by calling on the next most expensive generator to satisfy a particular level of demand. As such these costs reflected the marginal price of the actual *supply* of electricity from a power station.

Within the plans for a competitive supply market there was a requirement for this system of pricing generation to change. It was decided that the concept of marginal cost for generation needed to be retained but that market forces were required to drive the costs of actual supply. Such a system was provided through the creation of the electricity pool, known as the unified pool. The pool operates in a similar manner to the merit order system, taking into account the costs entered by generators for output, twenty-four hours in advance. As such the NGC, which runs the pool, is able to select generation output on a marginal cost basis for a forecast level of half-hourly demand.

About one tenth of electricity is actually traded on real-time cost price through the pool, the rest being purchased under contract although still traded via the pool (162). As pricing for demand is done on a marginal cost basis all generators at any one time receive the same price for electricity, with higher levels of demand reflected through higher costs and, therefore, higher prices.

At present, those customers outside the RECs franchise market are able to purchase directly from the pool via an agent and therefore take half-hourly prices for electricity. However, the number of customers wishing to be exposed to the historically volatile pricing of the pool has decreased (156). This was largely seen as being a consequence of the two major generators owning the majority of the price-setting mid-merit power stations and, in response, prompted the DGES to place caps on pool prices. Under the pool price cap the DGES struck an agreement with both National Power and Powergen that the average pool price should not exceed an annual average price per kWh for a two-year period from 1994. However, this average was time weighted at 2.4p/kWh and demand weighted at 2.55p/kWh (149). This led to trade-offs between the time and demand elements by National Power and Powergen; ultimately leading to increased volatility in price yet within the regulatory guidelines (88).

Many of the largest customers who were on a pool price contract became exasperated with pool price volatility, ICI for example eventually decided to build its own generation plant (143). Many other customers have reverted to tariff options offered by suppliers who hedge themselves against the fluctuations of pool prices through contracts for differences. Under these contracts the supplier agrees a set price for electricity with a particular generator(s) which, if exceeded by the pool-selling price, requires the generator to return payment to the supplier. If pool-selling price falls below the agreed price, then the supplier will have to make a compensatory payment to the generator. At present almost two thirds of electricity generated is purchased in this way (162).

Payments for generation are not only determined on the basis of electricity used. There is also a demand component. As such, customers with fluctuating demand levels may be unattractive to suppliers and thus find themselves paying a higher average cost per unit than those with a more constant demand profile (153). The customers with a constant demand profile are particularly attractive as they increase the number of units sold within the agreed capacity level.

Pool Mechanism for Pricing

The price of electricity from the pool is made up of several components and stages of pricing. Initially the NGC sets a system marginal price (SMP) which reflects the cost of the marginal generation required to satisfy the maximum demand within a half-hour period. All generators that are supplying the pool within this particular half-hour period are paid the same price for electricity generated.

In addition to the SMP. The Pool makes additional payments to the generators when capacity is scarce compared with demand. This is done under the Value of Lost Load/Loss of Load Probability (VOLL/LOLP) mechanism (153). This mechanism is supposed to provide a signal to the market on the cost effectiveness of marginal generation. As the payments for marginal capacity increase so potential investors in new generation will be encouraged to invest. The VOLL element currently stands at approximately £2/kWh although people are at a loss as to how the figure was derived (153). Some suggest that it was derived by dividing Gross Domestic Product by total annual electricity consumption (88). The value of the LOLP element rises when demand is particularly close to available capacity. It is very rarely greater than zero except under conditions of severe Winter temperatures (153) or when generation capacity is particularly scarce.

When the VOLL/LOLP is added to the SMP then the pool purchase price is set (PPP). In addition to this, a further payment is made for other services provided by the generators such as spinning reserve, black start etc., which is known as 'uplift'. When this is added to the PPP then the final Pool Selling Price (PSP) is arrived at. It is these often-volatile capacity and uplift payments, which have caused PSP to appear very 'spiky' (162). It was in response to these payments, essentially market failings, that OFFER introduced uplift management schemes and price caps.

Impacts of Privatisation on Industry Operations and Stakeholders

It has, at the time of writing, been seven years since the floatation of the RECs, six years since that of the generation companies, and two years since that of the National Grid. During this time there has been a supply business review in 1994, a distribution review in 1995 (and re-review in the same year), a transmission review in 1993, and an element of tinkering with the electricity pool.

Although the industry is in relatively early years in terms of development in the privatised and regulatory arena, there is still great scope for exploring the impacts of privatisation. These are now explored.

Supply

Those customers of the RECs supply business that are exposed to competition have been progressively switching suppliers since the opening up of their respective markets. The development of these markets is continuing.

At present competition within the electricity supply business is focused upon price (17, 128, 153), with many doubting the willingness of customers to pay a price premium for energy services. Many utilities have competed aggressively within the competitive market in order to win customers and have based their strategies on supplying the lowest cost product. Aggressive pricing policies are still a feature of the competitive market as suppliers attempt to remain cost competitive and hold onto market share in what is a volatile and complex market. However, annual electricity prices are now beginning to move away from the aggressive price cuts of 1994 and return to a stage where the future will see prices begin to rise year on year in response to a forecast increase in generation prices (Times 30/7/98).

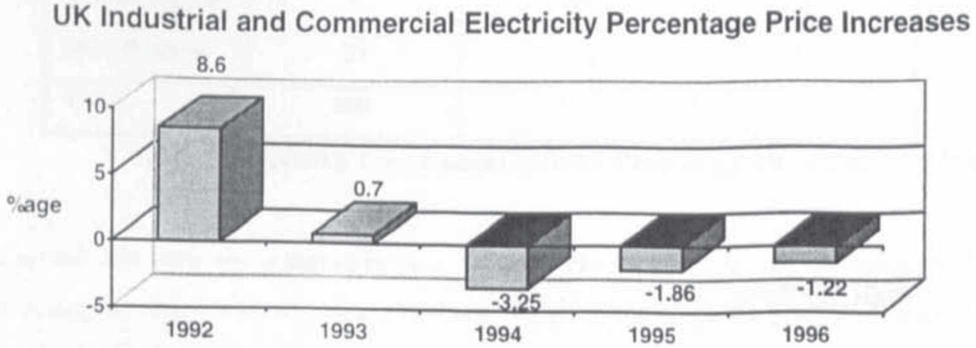

Figure 3.1 : UK Industrial and Commercial Electricity Percentage Price Changes (24)

Figure 3.1 reflects the trend of electricity prices that are drifting back to levels which could well rise above inflation in the medium term. This will occur most noticeably from 1996 onwards. However the effects of both the initial and on-going cuts in charges for Distribution Use of System (DUoS) of the 1994 Distribution review are likely to have the effect of masking these potential increases. This effect will be increased through the 1998 regulatory review of the NGC that advocated an X factor of minus three. However, it has recently been noted that generation prices are not falling and are appearing to rise (Times 10/6/98).

Within the over 1MW market, which accounts on average for 30% of electricity supply (152), the *local* RECs have seen their market shares by volume supplied fall from an average of 57% in the first competitive year of 1990/91 to 37% by 1994/95. Within the 100kW to 1MW markets, the market by volume supplied has fallen from 100% in 1990/91 (then still a franchise market), to 70% by 1994/95 (164). This loss of 50% of market share by volume corresponds to a 26% fall in terms of numbers of actual sites supplied, on a *local* basis. On a collective basis, RECs lost 33% of market volume and 7% of sites, representing the tendency of the very largest industrial sites to switch to self-generation or out-of-REC area suppliers (152).

From these figures it is not difficult to arrive at the conclusion that the RECs have effectively been competing against each other with relatively little competition from suppliers outside of the REC arena (when excluding generators). The market share that has been lost is attributable to a very small number of sites that have relatively high consumption levels.

On the basis of the figures given above the scope of competition in the supply market appears very limited and unable to attract independent suppliers who would offer competition to the RECs. In order to attempt to understand this it is necessary to examine the cost structure of a unit of electricity.

	0-100kW	100kW-1MW	Over 1MW
Generation	58	66	77
Supply	8	4	1
Transmission	5	6	5
Distribution	29	24	17
Total	100	100	100

Table 3.2 :. p/kWh Cost Components by Percentage for Supply Markets. (160)

Table 3.2 reveals the very low component of a customer electricity costs that the function of supply represents, falling to only 1% on a typical 1MW site. As such, the scope for price competition through focusing on reducing supply costs is very marginal. Distribution and transmission are monopolies and costs are regulated to ensure an acceptable allocation of costs. Thus far greater potential for price reductions could be achieved through focusing on generation cost reductions. The margins associated with supply are shown in Table 3.3.

	Turnover (£m)	Operating Profit (£m)	Margin (%)
Supply	13723	237	2

Table 3.3 : Typical Turnover & Profit for REC Supply Business (OFFER Supply Proposals 1994)

On the basis of the above information it would appear that the scope for competition in supply is dictated by the generation costs to the supplier. As RECs have equivalent access to generators who themselves set generation prices, either via the pool or via contracts, there is little scope for a particular REC or any other supplier to achieve significant cost differences in order to achieve a competitive advantage.

When considering the future of supply competition with regards to the fully competitive market in 1998 it is difficult to see how different suppliers can derive any real, and legitimate, advantages. An average profit on supply of £5 per domestic customer is not very attractive, particularly when considering that the forecast cost of an appropriate meter is in the region of £50 (23). Coupled with the cost of metering is the marketing cost of attracting a new customer which, from recent experiences in the gas market, is put at £25 to £50, plus an associated reduction in annual bill of £25 to £50 (23). Thus, even if the proposed use of 'standard profiling' of domestic customers is adopted, as used in Norway, there still remains a cost reduction of approximately £50 to £100 to be achieved before the majority of customers will switch supplier. The use of 'standard profiling' is in itself something of a compromise in supply competition, removing the cost reflective pricing principles that form the foundations of a truly competitive market.

Distribution

The distribution business of the RECs remains by far their most profitable activity. Prior to the regulatory review in 1994 RECs were achieving on average a 28% profit margin on the distribution business, as shown in Table 3.4.

	Turnover (£m)	Operating Profit (£m)	Margin (%)
Distribution	3928	1038	28

Table 3.4 : Typical Turnover & Profit for REC Distribution Business (150)

Initially, upon vesting in 1990, the 'X' factor of the RECs was set at plus 2.5% for all RECs except London Electricity (150). Thus an actual increase in annual revenue in real terms was allowed for the five-year period from 1990, for the purpose of network investment. The economic logic of this seems questionable as it would appear that the government was in effect implying that the distribution business of the RECs was operating rather efficiently and thus there was little scope for cost cutting. The rapid rise in the stock market value of the RECs, reflected in a 25% annual increase over the five years from 1990 (23), would indicate that the initial target of 'X' at plus 2.5 was extremely lenient. Indeed, the

RECs were worth a combined total of £15.48 billion in April 1995 compared to £5.18 billion in 1990 (88)

The DGES resisted the temptation to intervene in the excessive returns being made by the RECs and waited until the first distribution review in 1994. The proposals made by OFFER for the distribution business seemed, initially, to be severe. Initial reduction in DUoS charges of 11 to 17 percent, REC dependent, were ordered to be implemented at April 1995 (150). Additionally, 'X' was to be set at minus 2 for the entire five-year period to the year 2000.

The review was by far the toughest so far in the regulation of the industry and, as such, it was thought that the DGES had been sufficiently severe to redress the imbalance of the first five years of privatisation, reducing customer prices by 3 or 4 per cent per annum from 1995. However, late 1994 saw Trafalgar House launch a hostile bid for Northern Electric. In defence Northern Electric offered a range of benefits to shareholders that amounted to £500 million pounds in the form of increased dividends and one-off payments (151).

Upon becoming aware of this 'hidden' cash pile the DGES ordered a re-review of the distribution proposals. His response was to apply the MMC valuation procedure, as used in the case of HydroElectric, to the distribution business of the RECs. This applied a seven per cent rate of return and subtracted redundancy payments from the cost base. The effects were dramatic. The DGES made an additional 10 to 13 per cent initial reductions in DUoS charges, leading to total initial reductions of 21 to 28 per cent. In addition to this 'X' was tightened further from minus 2 to minus 3. As a consequence, REC DUoS charges would be 31 per cent lower in real terms by 2001 than they were in March 1995 (157).

Clearly, with such reductions there is no question that the consumer is benefiting. However, despite the apparent severity of the proposals there still followed a flurry of take-over activity. As such, the financial markets still deemed the RECs to be very attractive investments.

Generation

Investors have done equally well from the generation industry. Since 1991 the value of the two major generators has increased from £3.60 billion to £9.79 billion in 1995 (134). The DGES has no direct control over the generation business of the electricity industry, being as it was intended to be fully competitive and therefore not requiring regulation. This does not, however, mean that the DGES is powerless to prevent any generator abusing the market. The DGES is able to influence the pricing mechanisms of the Pool and, as such, is able to influence the behaviour of generators who are all required to operate through the Pool. Ultimately, the DGES is able to refer the generators to the MMC if he feels that such action is warranted.

Since privatisation probably the most important debates have centered on the operations and failings of the Pool system. This has primarily occurred through the inability of the Pool to adequately deal with the high levels of market power owned by the major generators, National Power and Powergen.

As early as 1992 the DGES became concerned by the apparent ability of the two major generators to influence the operation of the Pool (153). It was found that both National Power and Powergen were, for the vast majority of the time, setting the half-hourly pool price by virtue of the fact that they owned the vast majority of mid-merit power stations (oil and coal). Powergen was found to be behaving particularly badly by re-declaring plant as unavailable at the last minute, which resulted in changes to its licence arrangements.

Under threat of a MMC inquiry National Power and Powergen responded to the regulators request that they sell off 4000 MW and 2000 MW respectively of their coal and oil-fired power stations. Eastern Group purchased this generation capacity. In addition to this they agreed to the request that the average pool price should be nor more than 2.55p/kWh demand weighted and 2.4p/kWh time weighted on an annual basis. This price-cap came into effect in April 1994 for a two year period.

The effect could be considered to be disappointing. The standard deviation of the pool-price increased fourfold in the year 1994-95 (88). Also, the action may have sent a message to potential investors that the generation business was not beyond regulatory influences and thus was subject to increased risk. This may partly explain the lack of independent power producers competing with the two major generators, coupled with the fact that they may believe that Powergen and National Power still retain enough power to subject them to predatory pricing. Those independent power producers that are generating have almost exclusively tied themselves into long-term contracts for differences with suppliers and thus often run as base load, reflected by the fact that over 70% of electricity is purchased in this way (162).

The use of contracts has given generators direct incentives to reduce costs. However, until there is more effective competition in the marginal price setting of generation it is difficult to see how consumers can share in any reduced cost savings. In order to stimulate competition the IPPs would need to move away from base load generation under pressure of surplus capacity at this level. It is unlikely that new generating stations will be built to operate in mid-order where there is substantially higher risk than at base load. Table 3.1, shown previously, portrays the decline in market share of the two major generators but, as mentioned, this has been confined to the relatively non-competitive base-load market. This is reflected in Nuclear Electric's increase and that of the IPPs.

Actual purchase prices for generation did decrease in the early period after privatisation between 1990-96. However, many have argued that this is due to the ending of the generators obligations to purchase

British Coal at high market prices and the so called 'dash for gas', rather than due to competition (23). It could well be that without a substantial overhaul of the electricity trading markets competition in generation will never reaches the intensity that may have been imagined at vesting due to the potential dangers of pool price volatility, leaving contracts for differences ruling the market.

Recent Developments in the UK Electricity Industry

Government and Regulatory Changes

Many issues concerning the various businesses and operations of the UK electricity industry remain a popular topic of social, economic, industrial and political discussion and debate.

The Labour government, elected in 1997, has wasted little time in launching itself into a review of utility regulation with its 1998 Green Paper entitled "A Fair Deal for Consumers". The Green Paper covered several issues, such as the operation of the Electricity Pool, Boardroom salaries, and the protection of low income households in a competitive energy market (137). The government has also been seen attempting to find a means of ensuring a diversity of generation fuels, placing a moratorium on the building of new gas power stations whilst expressing a desire to see coal fired generation stations remain in operation. This was seen in the dealings of both National Power and Powergen with the Paymaster General, Sir Geofrey Robinson, who made attempts to persuade the two main holders of UK coal fired generation to extend coal supply contracts with RJB Mining.

Further influence by the Government has been seen in its desire to increase competition in the Electricity Pool at the mid and peak merit periods. In order to achieve this ends the government has suggested that National Power and Powergen dispose of up to twenty per cent of their coal-fired power stations or face the prospect of a MMC inquiry. Powergen has responded by offering to comply with this arrangement, although this offer has come at a time when it has resurrected its attempts to purchase a REC in the form of East Midlands Electricity plc.

However, the Green Paper has not suggested any radical changes to the actual method of regulation of the electricity industry as it currently stands at 1998 beyond proposing the creation of a dual regulator encompassing gas and electricity. The electricity regulator has confirmed as much in his response to the 1998 Green Paper:

> " I welcome the Governments Green Paper and its emphasis on building on the experience of using existing regulatory arrangements.... I am pleased by the endorsement of price controls which give companies the incentive to improve efficiency and reduce costs."

(155)

However, there is a proposed change to the structure of the REC business which could have severe consequences for the ability of the distribution and supply businesses to co-operate in the area of DSM. The regulator, in agreement with the Government Green Paper on Utility Regulation, has stated his intention to examine the feasibility of splitting the REC business into two separate companies of Distribution and Supply, each in their own subsidiary. A range of measures have been suggested to ensure that Distribution and Supply remain at arms length:

- Ensuring use of system contracts are formally established between Distribution and Supply.
- Avoiding the sharing of facilities between businesses, including staff transfers.
- Ensuring staff have responsibilities within the scope of one business only.
- The requirement for separate management teams for the two businesses.
- Minimising scope for corporate headquarters activity.

(155).

The implementation of these changes would cause DSM through Energy Services to be difficult to implement. Any restriction on the transfer of data, knowledge, or capabilities between the Distribution and Supply businesses would create an information gap in the planning of DSM programmes. Accurate planning of programmes would become more expensive and time consuming for the Distribution company as it is unable to access information on customer billing held by the Supply company. Additionally, the funding of DSM measures through novel billing techniques facilitated through the Supply business would become impossible. It remains unclear as to how the regulator expects DSM programmes to be funded beyond his opinion that the EESoP revenues could be utilised to target energy efficiency to provide network benefits (151). Such funding is commendable in so far as it solves the issue of capital expenditure yet it fails to address the issues of lost revenues associated with reduced sales.

Electricity Trading Review

On 23rd October 1997 the Minister for Science, Energy and Industry announced a review of the electricity trading markets. OFFER duly obliged and released its interim conclusions on electricity trading revisions in June 1998 (156). Within the report were a number of proposed changes to the electricity trading markets :

- Development and progression of forwards markets.
- The formation of an organised short-term bilateral market (at least 24 hours ahead to 4 hours ahead of each trading period).
- A balancing market (4 hours ahead to the completion of each trading period); and
- A settlement process for imbalances

Each of these trading mechanisms is expanded upon:

Forwards Markets

Trading in forwards markets will involve bilateral contracts between buyers and sellers. These contracts will cover pricing and volume agreements and other clauses and conditions on arranged terms (156). The actual length of contract will be as required by the parties involved with some, for example, buying electricity on terms agreed for several years into the future, whilst others may enter into short-term contracts much nearer to the actual time of production and delivery. The likely result will probably be a portfolio of contracts leading to greater flexibility.

Short-Term Bilateral Markets

Under this proposal a Market Operator would be responsible for organising a short-term bilateral market up to the point where the System Operator takes control of balancing the system (156). It is proposed that this market would operate from 24 hours, up to 4 hours, ahead of the trading period in question. The market would be operated on the basis of generators and suppliers making simple offers and bids which would represent firm financial commitments at the agreed terms, trading in standard products such as 'base-load contracts' and 'peaking contracts' as well as 'half-hour contracts'.

Price signal for the short-term bilateral markets will be facilitated through the on-screen display of the last contract to be struck.

Day-Ahead Auction

This would take the form of the pool as it exists now. It is believed that this market will not be required if the other proposals are successful.

Balancing Market

The System Operator (currently NGC), is responsible for ensuring that system supply and demand are matched and the system balanced. It is proposed that the System Operator will, when the markets have closed, purchase required generation or demand reduction. Participants in the trading period in question will no longer receive the marginal price for electricity but that which they have arranged through contracts. The System Operator will then charge participants for any shortfalls in their contract cover with a balancing price (156).

It is envisaged that the balancing market will operate from 4 hours before the end of a trading period (half-hour) up until the end of the trading period itself. Participants would then supply information to the market on the prices at which they were willing to change upwards (increments) or downwards (decrements) from the physical conditions at which they were in at the beginning of the four hour period. All offers and bids would be required to be location-specific (156).

Settlement

This market would refer to the electricity purchasing short-fall of market participants. The System Operator, being responsible for balancing the system, will be required to purchase contract cover to accommodate the lack of contract cover at the margins of electricity purchasing. Suggestions for the actual price mechanism range from a volume weighted average to a marginal price (156). The exact mechanism to be utilised has not as yet been agreed.

The trading proposals have seen a concerted attempt at making the demand-side of the market become more involved in setting the price for electricity. Demand reduction bids, it is suggested, increase the balancing options open to the system operator (156). OFFER acknowledges that the participation of the demand side might be limited to certain customer classes due to the cost of equipment required to deliver real-time price signals and also due to many customers not wishing to alter demand regardless of price signals (156).

The proposals for the trading markets will require electricity suppliers to have a sound knowledge of their electricity demands so as to avoid exposure to clearing prices set by the System Operator. As such, the knowledge of load profiles at a customer level that are delivered through DSM could prove to be very useful in demand side bidding. On this basis the proposals may encourage RECs to become more involved with analysing customer loads and exploring alternative benefits of DSM. Despite this benefit there is the potential downside of a more fluid electricity contracts market enabling larger industrial customers to purchase electricity on short-term contracts. As such, long-term supply contracts which are a feature of DSM via energy services could be difficult to obtain. However, it is likely that only the very largest customers could afford the time or expertise required to manage the purchasing of electricity within the proposed markets.

European Union Integrated Resource Planning and DSM

On the 20 September 1995 the European Commission proposed a draft Directive aimed at requiring gas and electricity companies to adopt new planning techniques. The Directive was developed in response to the EU's commitment in 1990 to stabilise CO_2 emissions in the year 2000 to those at 1990. In order to meet this commitment various energy saving and energy policy research programmes were initiated. These included SAVE programmes I/II and Joule Thermie programmes (106). The aim of these programmes was to re-establish the importance of energy efficiency in the EU's commitments to stabilising CO_2.

A major thrust of the SAVE programmes was the belief that major institutional and market barriers restrict economically viable investment in energy efficiency measures (106). Further to this, the EU Council asserts that utilities have a key role to play in the achievement of these goals by adopting planning systems which treat energy efficiency investments on the same basis as energy supply investments (106). The EC Council give further weight to the proposal of this thesis that electricity utilities should focus upon delivering energy services which are co-ordinated and developed to assist in the quest for increased demand side involvement in the optimisation of asset utilisation, stating:

> "States must devise mechanisms which decouple the volume of commodity sales from profits........gaining a return form energy efficiency investment is central to the distribution utilities embracing their new role as energy service providers and not simply 'commodity' sellers."
>
> **(106)**

Further reasons for increasing energy efficiency and demand side involvement include the EU's substantial reliance upon imported fuels, the large amounts of capital investment in new plant required to meet forecasts of demand growth, the release of extra capital through lower energy costs enabling increased purchasing power and macroeconomic demand, and increased competitiveness of industry as a result of lower energy costs (106).

On the basis of the above, it appears that the EU Council is primarily focused upon environmental concerns associated with energy production and consumption and views energy efficiency as a means to address these concerns. Indeed, demand side investment by utilities in an attempt to optimise network asset utilisation can involve energy efficiency. However, asset utilisation does not solely concern itself with reducing peak demand on a distribution system and can actually involve building load away from times of system peak. Enabling utilities access to mechanisms that can achieve the primary aim of energy efficiency may well encourage utilities to grow load and hence increase overall electricity consumption. The positive effect on environmental emissions could, as a result, be reduced in accordance with the end mix of generation required to service this growth.

The new planning techniques referred to above include the adoption of Integrated Resource Planning (IRP). With regards to the electricity utilities, IRP techniques allow an evaluation of investment opportunities in the alternatives of the supply side and the demand side. The evaluation of the options is designed in such a manner so as to allow the two alternatives to compete on an equal economic basis. The EC directive places five requirements on the utilities within Member States when considering investment in energy infrastructure:

1. establish procedures whereby electricity and gas companies periodically present IRP plans to the competent authorities to be determined by Member States.

2. examine whether the economic energy efficiency measures identified by the IRP plan are undertaken.

3. review existing legislation in this area to ensure that mechanisms are established which permit electricity and gas distribution companies to recover expenditure on energy efficiency programmes provided to consumers. Such mechanisms should ensure that distribution companies which undertake DSM are not revenue losers.

4. encourage electricity and gas distribution companies to:
    - set up comprehensive information programmes aimed at informing consumers on rational energy efficiency choices.
    - provide, where necessary, incentives to consumers to carry out energy efficiency investments.
    - set up DSM programmes targeted at low income energy users who spend a disproportionate amount of their disposable income on energy.
    - invest in energy efficiency through the creation of subsidiaries offering third party finance facilities to consumers, or support the efforts of existing third party financing companies.

5. promote the integration of DSM options into capacity tendering procedures in the distribution sector where these exist.

Steps to be taken Towards IRP: Proposal for a Council Directive to Introduce IRP in the electricity and gas distribution sectors (106).

The proposed draft directive was adopted on the 20th September 1995. Upon its subsequent analysis by the European Parliament on the 12th November 1996, the proposal was revised in several areas, as listed below:

- Application of a codecision procedure.

- Reduction in energy intensity of at least 1.5% per year.

- Establishment of mechanisms which permit sale of energy-saving services without adversely affecting the competitive position of electricity and gas and provide an incentive to utilise rational planning techniques.

- Provision of clear costings of energy supply services for customers.

At the time of writing (July 1998) the proposal is before the European Council for a common position.

The Council Directive, in the form stipulated, will compel electricity utilities within the UK to adopt IRP in all investment decisions related to capital expenditure on network assets. This will by necessity require electricity distribution companies to have considered demand side measures as an alternative to traditional supply side measures to address network reinforcement and expansion. However, the search for a common position will require the proposal to accommodate the differences in market and industry structures between member states. As such the UK, whilst in a position whereby it already meets some aspects of the proposal, is likely to amend or reject certain aspects which it feels are incompatible with the UK electricity industry.

At present, electricity distribution companies within the UK are not compelled to put forward IRP plans when proposing investment in the electricity distribution network to the regulator. Additionally, there are no recognised revenue recovery mechanisms in place whereby distribution companies can recover revenues which are lost as a result of reduced sales associated with DSM programmes designed to defer network reinforcement.

However, the UK does comply with the demands of the proposal to provide comprehensive information on energy efficiency to consumers. This requirement has been fulfilled through regulatory obligations on electricity companies to provide telephone advisory centres to enable consumers to access expert advice on energy efficiency (152). Other requirements of the proposal would appear to be self-fulfilling due to the opening of the electricity supply market to competition. For example, customers wishing to obtain clear costings on energy supply services are able to do so as a result of electricity utilities developing energy services offerings as a competitive tool. The feature of developing a mechanism whereby investment in the demand side can be recovered by electricity utilities remains an unresolved issue in the UK at the present time.

The fundamental problem with the Directive proposals in terms of the UK lies in the treatment of investment in the demand side by the regulator and also in the volume driver present in distribution revenues. Demand side investment is not allowable as capital expenditure and as such can not be recovered as within DUoS allowances. The volume driver, allowing fifty per cent of the DUoS associated with any increase in distributed units above forecasts of sales, also distorts any investment analysis when comparing the demand side investment with supply side investment. This issue is explained further in Chapter 4.

The Directive on IRP is likely to have to be compromised to take account of the industry structure within the UK. Alternatively the industry regulator will be required to reassess the treatment of capital costs and revenue recovery in order to enable the demand side and supply side to be assessed on equal terms. The exact format of the proposals, and definitive implications of IRP for UK electricity utilities, are yet to be resolved but could enable DSM to become a more effective tool in utility planning than it presently appears to be.

CHAPTER 4

REGULATION OF THE UK ELECTRICITY INDUSTRY AND ITS IMPLICATIONS FOR DEMAND SIDE MANAGEMENT

Introduction

Regulation of the UK utilities is carried out by relevant Director Generals with the assistance of Offices of Regulation. At present the Director General for Electricity Supply (DGES) is Professor Stephen Littlechild, originator of the RPI-X price regulation formula, assisted by the Office for Electricity Regulation (OFFER). Within the UK price regulation under RPI-X has been the rule for all of the privatised utilities. The main alternative to price regulation, that of rate of return, has been rejected by the UK government and its advisors for reasons to be explored in this Chapter.

This Chapter will aim to explore the two major types of regulation, namely Rate of Return and Price regulation. Following this there will be an examination of how the electricity industry has been restructured into its component parts, the rationale for doing so, how regulation has affected each of these component parts, and a brief account of the impacts of privatisation and regulation on the main stakeholders of the industry.

A final section will examine how the regulatory arena has, from initial privatisation, influenced the scope for the implementation of demand side management, and the related area of energy efficiency, within the electricity industry. Suggestions as to the future prospects for DSM and EE within the industry as it exists will conclude the chapter.

Privatisation and Regulation of the UK Utilities

The privatisation of the electricity industry is not an isolated phenomenon within the UK economy. Privatisation of UK utilities was a matter of conservative government policy over the entire period of the 1980's, policy which was intended to shift public ownership and decision making to the private sector.

The objectives for privatisation were several, and not only based upon the desire for increased public to private ownership. Many powerful influences within the Conservative Party believed strongly that nationalised industry was inefficient and too heavy a burden on the taxpayer. In addition to this economic issue, other objectives for the privatisation of the utilities have included the break up of

Union power, the creation of a share owning democracy, and generation of Treasury revenue, many of which have been pursued, it is suggested, for political ends (23, 72, 90).

The privatisation of nationalised utilities is a contentious and emotive issue, primarily due to the fact that the utilities provide services fundamental to civilised life. Opponents of privatisation argue that national ownership is necessary in order for the government to achieve policy objectives, particularly those of a social nature (88). Others feel that the utilities are simply too valuable to sell into the public sector, indeed a former conservative Prime Minister described such a concept as being akin to 'selling the family silver'. However, supporters of privatisation see it as a necessity in order to shake out the inefficiencies of state ownership, inefficiencies that can only be corrected through the application of market forces (87).

Whatever the real objectives were behind privatisation, it is apparent that the privatisation process is now almost impossible to reverse without unrealistic expense and upheaval. Additionally, the present Labour government appears reluctant to become too deeply involved in the workings of the privatised utilities having removed national ownership of utilities from its constitution. As such the privatised utilities are destined to remain in the private sector under the rule of market forces, where possible, or regulation where monopolies remain.

Regulation of Utilities - Why Regulate?

Rate of return regulation has been the dominant method of regulation of the US utilities since the 1960's. It was from the US experiences with regulation that the UK government sought to construct its own regulatory bodies to deal with natural monopolies inherent in many utility privatisation (7).

The concept of regulation has been defined by many economic theorists, definitions which all essentially imply the same meaning of regulation. One such economist, Selznick (78) described regulation as "sustained and focused control exercised by a public agency over activities that are valued by the community". As such regulation is used to describe the direct intervention in the operation of a market and involves a wide variety of objectives such as the protection of employees, protection of consumers, protection of the environment and also protection of the regulated industry itself. Regulation can appear in many forms, being implemented through restrictions on product price, production process, and product quality (22).

Regulation is often seen as a necessity within any industry where a particular firm can be seen as having a monopoly over the supply of a particular product or service. The term monopoly means, literally, 'single seller' (22). Since the firm is effectively the sole supplier of the product then the demand curve facing that firm is the market demand curve. The degree of elasticity of any product or service depends to a large extent on the availability of substitute products. As such, the elasticity of demand for electricity is very low, with large changes in electricity prices being met by the consumer due to the unavailability of a suitable alternative service or product. The same is true of the distribution business of a REC. The high market entry barriers associated with extremely large capital costs restrict other companies from competing with REC's to distribute electricity.

Within an uncontrolled monopoly the seller can charge whatever price it thinks the market will bear. If this price is exceeded then the monopolist will be faced with the prospect of fewer sales and hence overcapacity. Within the electricity industry, where the product is such a vital part of peoples' everyday existence, there is great scope for the monopolist to abuse market power and charge prices substantially higher than would be achieved in an atomistic, highly competitive, market. It is the importance of electricity as a cornerstone of modern life that dictates the necessity of regulation.

It is one of the duties of the appointed regulator of a particular industry (which in the electricity industry is the Director General of Electricity Supply - 'DGES'), to protect consumers from the potential abuse of the monopolist position that RECs find themselves in (151). Such a position is seen to occur within the Regional Electricity Companies (RECs) in both the distribution business, classed as a natural monopoly, and the supply business which is being gradually opened to market forces of competition.

In addition to responsibilities and concerns for the consumer, the regulator must ensure that the other stakeholders in the industry, such as shareholders, are treated in an equitable manner. In the case of shareholders this entails ensuring that they are able to receive a fair rate of return on their investment, which by implication requires the regulator to provide an environment within which the regulated industries can continue to operate.

Regulatory Agendas

Regulation can occur on both economic grounds and social grounds. Social regulation is carried out in order to combat market failures, protect the poor, and wider social concerns such as protection of the environment. Economic regulation specifically deals with the prevention of abuse of monopoly power, competitive structure and contribution to economic growth (23).

Social regulation often requires the regulated industry to provide information to customers, fulfil standards, and obtain prior approval for business plans. The provisions of social regulation are used to rectify market imperfections, such as those that may occur through the lack of information to the end consumer to enable an informed purchase decision. Standards are set in order to ensure that expected minimum levels of service are delivered to the consumers who, unless represented by a regulatory body, could often find themselves too few in number to influence company behaviour (151).

Another aspect of social regulation which is a contentious issue is that of protection of the environment. The harmful effects of pollution on the environment by utilities, such as that associated with fossil fuelled generation, is a matter which needs to be considered. Whether such effects are accounted for as external costs and thus given economic consequence is a matter of debate in terms of appropriate values and allocation of these costs.

The standards that may be introduced as part of social regulation come in three forms; target, performance, and specification standards can be utilised and reflect the extent to which the regulator is involved in maintaining control over the industry. As such targets represent minimalist, arms-length, regulation, whilst specification standards represent the other extreme.

Regulatory Mechanisms: Rate of Return Vs Price Capping

The literature advocates that regulatory mechanisms fall, primarily, into two distinct camps. The first is that of Rate of Return (RoR) Regulation, commonly utilised in the United States, which allows regulated industries to receive a profit that reflects a pre-determined percentage of their asset base. As such, RoR regulation can be seen to fix profits. The second is that of Price Cap Regulation, utilised in the privatised utilities of the UK, which determines a maximum level of prices for a product and therefore does not restrict profit.

Rate of Return Regulation

RoR regulation is commonly justified on the basis that it strongly encourages firms to invest and as such is deemed to be beneficial to the quality of service delivered to the consumer. Observers have claimed that RoR regulation is beneficial in so far that it enables regulators to restrict monopoly pricing through closely controlling a company's profits (47). The regulator is able to set prices based upon the rate of return required by the industry and on this basis is able to set optimally efficient prices. In addition to this, the regulator is able to meet social concerns by setting up cross-subsidisation of customer groups.

The major difficulty associated with RoR regulation is that of finding a suitable figure to apply to the industry in question (39). Within the US the common approach has been to examine companies across the industry and then derive an appropriate average RoR, taking into account any unique differences in circumstances. Due to the nature of the approach the RoR has been based on both efficient and inefficient companies, with the potential problem of excessive returns to some companies and a fall in profits and quality of service in others.

RoR regulation is not without its critics for a number of reasons. A firm that is subjected to RoR regulation is able to pass on costs to the customer in the knowledge that it will be able to earn a suitable rate of return regardless of the effectiveness of the investment. Some commentators have claimed (31) that companies regulated by RoR have higher than average remuneration to employees, larger perks, and general cost inefficiencies that a competitive market would eliminate. A further problem associated with RoR is that of 'regulatory capture'. It has been suggested (66, 87) that some industries actually encourage regulation under RoR. This occurs as industries believe that regulation protects them from what would otherwise be a highly competitive market. With the large political influences associated with such powerful industries as utilities it has been suggested that regulators have too often become sympathetic towards their cause (23).

A further problem associated with RoR regulation is its high cost. Vast quantities of data are required in order to calculate a suitable rate figure, data such as operational and capital costs, cost forecasts, cost allocation, and so on. Such data is also burdensome to collect and it has been suggested that companies could find it relatively straightforward to exaggerate costs and hide their true cost structure (38).

At present the US is beginning to move away from the RoR regulation of the electricity industry. The notion of 'contestable markets' has been advocated as a driving force behind this change of direction for US regulation. A 'contestable market' is deemed as being any market where the costs of entry to, and exit from, the market for new firms are insignificant and as such are not barriers. As such, when prices rise above marginal cost then new entrants will be drawn into entering the market until increased competition forces down 'supernormal' profits and prices return to reflecting marginal cost. If prices then fall below marginal cost then firms will exit the market without cost until the same equilibrium is again reached (22). Claims concerning the effectiveness of this approach could well be over zealous, and the theory does not apply itself readily in the case of certain natural monopolies such as distribution, with associated very high entry costs. However, within monopolies with potentially competitive areas such as electricity and gas supply, the theory could hold reasonably well with minimal, if any, economic regulation. It is, as such, becoming apparent that the US is moving towards the implementation of competition in both generation and supply of electricity.

Price Regulation

Price regulation brings about different incentives to RoR regulation. This occurs due to the fact that price regulation realises the fact that costs of a company and the capital base are not independent. As such, one of the main features of price regulation is the fact that there is a very strong incentive to minimise costs as this represents the major method through which companies can readily increase profits (47).

Within the UK price regulation is achieved through the '*RPI-X*' formula, RPI being the Retail Price Index and X being a factor set by the regulator in response to the anticipated efficiency gains that are expected of the industry under regulation. Price regulation is claimed to have several advantages over RoR regulation. the first is that the amount of information required, when compared to RoR, is modest.

As such, unlike RoR regulation, contact with the regulated industry is of a modest level, the chances of regulatory capture are small. In addition to this, price regulation can be applied to selective parts of the business, and not to its entirety. However, probably the most beneficial aspect of the mechanism is that it provides incentives to reduce costs and inefficiencies, as profits can then increase (92).

Despite the benefits associated with price control through RPI-X there are associated problems. The first is that the public perception of the industry under regulation is tainted if the price controls are, for whatever reason, too lenient and lead to excessive profits. This has been the fate of many privatised utilities within the UK. This in turn leads to the regulator being pressurised to redress the perceived imbalance. As such the regulator could be viewed as moving away from price regulation and into profit regulation, adjusting the 'X' factor to reduce company profits (93). As such, price regulation can be seen to move towards RoR regulation under certain circumstances and thus there is the danger that the problems associated with this form of regulation, discussed previously, could occur.

The setting of the 'X' factor is also not an easy task. Price regulation was originally claimed to be less costly than RoR regulation. However, in order to set 'X' regulators still require information on the cost of existing assets, the cost of capital, and forecasts of productivity and demand (151). Such information is very similar to that required for RoR regulation, blurring the lines between the two types of regulation.

However, once the cost base and X have been set any increases can not be passed on to consumers. Thus companies have the incentive to efficiently control expenditure. This incentive to minimise costs can be further enhanced in the absence of a mechanism for the benefits of cost reduction to be passed on to the consumer, allowing the REC to retain accumulated profits.

As with RoR regulation a major feature of being able to calculate a suitable price cap is the ability of the regulator to calculate a suitable cost of capital. This is then required to be applied to the capital asset value of the business. When multiplying the cost of capital by the asset value the regulator will arrive at a minimum profit that investors require to be delivered in order for them to invest in the business. This figure is then combined with operating costs and divided by forecast of sales in order to calculate the required average revenue per unit of product sold (150).

A further problem associated with price-cap regulation is one of a political nature in so far as the regulator is appointed by the government and is given a high degree of discretion. As such, regulators have often been criticised as having too much of a free reign in the manner in which they are allowed to influence the industry under regulation (23). Indeed, the only avenue for action against the regulator lies with the MMC, a fact that is pointed out by some as a serious short coming of UK regulation (7, 23).

Vickers and Yarrow (93) point out the imbalance in information between the regulator and the regulated, leading back to the *principal - agent* theory that evolved from RoR regulation, which sees the firms as having access to more information than the regulator. A way around this is through the regulator developing yardstick judgements through comparison of firms with one another. This has already featured in the Distribution Review of 1994 and Re-Review of 1995.

There is a general consensus that price-cap regulation is preferable to that of RoR. However, Liston (46) argues that regulation must be flexible in response to the stage of liberalisation and the market in question. On this basis it is suggested that price regulation is beneficial for the first five years of a competitive market where competition needs to be nurtured, and that after this period RoR will be more beneficial. There are further claims (46) that RoR regulation, when implemented, deters new market entrants by virtue of the fact that it acts as both a ceiling and a floor in terms of price setting. As such, new entrants are deprived of the freedom to set prices in an attempt to win market share. In addition, if entry is forbidden or restricted by high barriers, such as high capital investment, then a price-cap makes little sense as companies have no incentive to price below the cap, only to severely cut costs. On this basis, Liston argues that price regulation is little more than a variant of RoR regulation.

However, the view of Liston is countered by Litllechild and Beesley (47) who suggest that price-cap regulation is particularly suitable to industries where rapid changes in technology are able to create a more efficient and therefore competitive industry. Indeed, when first proposing the idea of price-cap regulation Littlechild suggested that it be used for the first five years from privatisation.

There are claims that the UK has achieved a degree of success through the use of price-cap regulation (18, 20). The process of setting the price-cap is relatively transparent and prices have fallen in real terms since vesting for all utilities except that of water. Cost inefficiencies within the utilities have fallen, as reflected in the reduction of labour requirements for core activities (3) and also through the performance in share prices. Within the 'contestable' parts of the industries competition has and is continuing to develop, as seen through gas supply competition in the UK by 1998. Also, price-cap regulation is claimed to be proving itself to be more cost effective and less time consuming than RoR regulation may have been (18,20).

However, there is another side to the coin, with several commentators (23, 88) claiming that there has been no evidence to suggest that privatisation has increased the efficiency of the utility industries. Indeed, the increases in profitability of the utilities is to some commentators proof that the regulation of the utilities has been too lenient.

The privatisation of the UK electricity industry will now be considered. Its resultant effects on the structure of the industry, and upon its various stakeholders, will be examined. The implications of privatisation for the future of DSM programmes will be considered and assessed.

The UK Situation At Present

Economic regulation in the form of price controls, quality controls, public ownership and public franchising have all been utilised at some point in British history. The previously nationalised industries are good examples of the regulation of industry by external forces, i.e. the public, in order to ensure that the market functions in the desired manner. Since privatisation, regulation has not disappeared from the UK utility industries. Price regulation is strongly enforced in monopoly areas of the utilities businesses, determined by an independent, although government appointed, regulator.

Areas of UK utility business that were deemed contestable markets are now, to varying degrees, competitive. The extent of this competition and its viability is still widely debated, with strongly opposing views (23, 127).

Within the regulatory environment of the electricity industry OFFER practices social and economic regulation in both the supply and distribution business areas of the RECs. Within distribution there is economic regulation through the use of price caps on received revenue and social regulation through the requirement on the RECs to meet Standards of Performance (SoP) targets. The supply franchise business is also subjected to economic regulation through a revenue price cap and subjected to social regulation through SoPs, an example of which is seen through the funding of the Energy Saving Trust (EST).

The full extent of regulatory influence and policy with regards to the UK Electricity Industry is explored in the following pages. The break up of the industry at privatisation is examined, along with the relevancy of regulation for each component of the industry.

The Implications of Regulation for Demand Side Management

Prior to Privatisation the CEGB and the Government paid little attention to the concept of altering patterns of electricity demand, particularly where the effect would have been to reduce consumption. Much government effort was expended to ensure the survival of indigenous fuel and equipment supply industries. It has been suggested that this was also due to the fact that the vested interests of the large and powerful electricity industries helped to push the case for maintaining consumption levels as high as was possible (88).

Probably the only serious attempt to influence demand patterns of customers in the days of nationalisation was seen through the promotion of off-peak consumption. This was introduced in the late 1970's to early 1980's in order to maximise the use of base-load nuclear power stations which by their nature produced output for a twenty four hour period. As such the off-peak base load was utilised in the form of storage heating on what became known commonly known as the economy seven tariff. The effect was to have a double benefit for the CEGB and Regional Electricity Boards as the increase in load at the off-peak period also made greater use of transmission and distribution assets that had large fixed costs.

In the related area of energy efficiency, successive governments made varying attempts to provide information on techniques and devices which could reduce the end-user's consumption.

Distribution

The vast majority of REC profits are derived from the distribution business. Typically, the distribution business will account for 90% of the profits of the entire REC business (151). This profit is achieved through the operation of what is termed a 'natural monopoly'.

The regulator is charged with enabling the on-going viability of the distribution business whilst ensuring that all stakeholders are able to achieve a fair level of satisfaction. This satisfaction may come in the form of a certain level of expected quality of service for the consumer, or an acceptable rate of return on investment for the shareholder.

Due to the nature of price regulation that has been imposed on the distribution business, and the fact that the government desired to keep the regulation of the industry light-handed and low cost, the regulator is unable to dictate the nature of investment undertaken by the REC.

The regulator must consider the operating costs and proposed capital expenditure of the RECs and make a judgement as to there fairness. As such yardstick comparisons have been used in considering REC expenditure plans but the regulator makes no attempt to influence REC investment decisions:

> " ...neither the underlying calculations [for setting price caps] nor the proposed price control itself prescribe the ways in which RECs can actually spend their revenues in the future." (151)

As such RECs can effectively trade-off one area of the distribution business with another provided that they maintain their obligations to consumers. As such RECs could, for example, reduce expenditure on operating costs and channel it into capital investment as long as the REC remains within regulatory standards of service.

Considering that price regulation is in operation the theory behind it would suggest that REC distribution businesses have an incentive to reduce costs, whether operational or capital expenditure. As such, the regulator expects DSM schemes leading to the optimisation of distribution assets to be implemented where this is economically viable (151).

> "To avoid a reduction in the quality of supply received by customers, plant replacement will need to increase, alongside the continuing development of methods to extend plant life."

(151)

In addition to the incentives implied by price regulation, the DGES has reduced the revenue driver in the distribution business from being 100% volume related. The revenue driver has been reduced to 50% volume related on the basis that distribution costs do not increase, in general, in proportion to volume sold (151). The other 50% of the revenue driver is linked to customer numbers, forecast in advance by the RECs. OFFER stated at the time of the proposed change to the distribution driver that the remaining 50% volume related driver would leave an incentive to RECs to continue to market electricity whilst allowing them to remain objective on issues of energy efficiency.

With regards to placing a levy on consumers to pay for DSM programs, OFFER has so far refused to do so. The sum of £100 million, already raised by a levy on franchise consumers, and to be used by the Supply business under Standards of Performance has been deemed as a suitable amount with which to experiment with DSM. The DGES has stated that to raise more revenue for the purpose of DSM (and Energy Efficiency) is to go beyond regulatory remit and into the realms of fiscal policy (151).

In addition to the changes made to the volume driver OFFER also proposed an increase in the amount of revenue that a REC could retain through reducing system losses. As a result of this the proportion allowed to be retained by RECs was doubled. Effectively this produces, based upon a reduction in annual losses of 1 GWh , an increase in the maximum allowed revenue of £30 000 (151).

The reduction of the volume driver can be seen to have both positive and negative effects upon the practice of DSM. As the volume driver was reduced and considering that RECs are, by definition, not able to make a return on electricity not distributed, any reduction in load will be seen as having an adverse effect on revenue. As such, a DSM program for the purpose of reducing the peak load on a system facing reinforcement will be required to compete on an uneven basis. Thus the negative of lost revenue, although halved by the volume driver being at 50%, still remains and could render void potentially viable DSM programs.

In addition to the above, the volume driver reduction has an equally negative effect on the RECs' incentives to increase load on the system at times of low demand. The reduction in returns on such activities, which optimise the use of fixed assets and could therefore eventually result in lower DUoS charges, could be seen to have a negative impact on load growth activities. The reduced revenue from increased sales has significantly altered the attitudes of certain RECs towards research and development into electro-technologies. These electro-technologies provide a way through which RECs can compete with fossil fuel powered technologies, particularly gas. The financial appraisal of such products is further hindered when considering the substantial marketing costs involved in promoting new technologies.

It would appear that the regulator has blurred the lines between DSM and energy efficiency. DSM is continually mentioned within OFFER documents under the heading of energy efficiency. However, DSM is not energy efficiency per se. Energy efficiency provides a means through which RECs can achieve the optimisation of the use of network assets. As such load growth, load shifting, dynamic load shaping, and valley filling are equally as much a part of DSM as load reduction and peak clipping. The regulatory approach has, however, only addressed the last of these two aspects of DSM and has to an extent militated against the other aspects.

A more long term effect of the regulatory changes to the revenue driver is offered through the 50% link to customer numbers. On this basis REC fortunes are, to a certain extent, tied up with the economic well-being of the area that they serve. A customer that is lost, for example, due to an inability to remain competitive, means a corresponding permanent loss of revenue. When considering large industrial customers this revenue could be quite significant. Much has been written about the inability of industrial consumers to identify energy savings for reasons such as lack of time, lack of knowledge, insufficient discretionary expenditure etc. As such, RECs are in a position where they can potentially resolve these problems through innovative contract offerings. The opportunities to stabilise the revenue base from such activities should not be overlooked.

The changes to the amount of revenue that a REC can retain through reducing losses has increased the economic incentives for DSM, although to a minor extent. This occurs due to the fact that the majority of losses on the network will be heat losses of the form I^2R (the square of electrical current multiplied by resistance of the conductor). As such any reduction in load, particularly at system peak, will reduce losses and therefore increase maximum allowed revenue.

The method through which the regulator assesses capital investment, and subsequent returns, can also be seen to influence DSM. The regulator has stated that he sees no reason why RECs should not be exposed to the market risk of capital investment (151). As such, RECs are not allowed to recover proposed capital expenditure within a review period (five years). Indeed, the regulator only allows the RECs to recover depreciation costs and project financing costs, thus there is no guarantee of a return on investment above the cost of borrowing. This, in theory, should provoke RECs into thinking very carefully before making capital investment and consider issues such as future load growth, customer mix etc. in great detail. As such, the option of DSM when considering reinforcement on network systems with a high peak load, having a poor load factor, and almost negligible growth, should look very favourable. Thus the business environment created by the regulator is one in which the RECs are guided towards seeking the optimal capital investment plan.

There is, however, a dangerous side to the regulation of capital investment as described above. Under the price control RECs are able to retain efficiency savings. As such RECs may overstate capital investment plans, and it was suggested that they did so by the DGES in the 1994 proposals, by as much as 25% (151). This could be interpreted as an attempt to maximise revenues and therefore resultant profits. It then becomes difficult in a future review to ascertain whether or not the associated increases in profit are due to efficiency gains or an overstatement of investment plans. As such RECs have an incentive to increase their asset base in order to obtain an increase in profitability. The extent to which this philosophy prevails may reveal itself over time and reflects the 'rate of return' nature of price regulation.

Supply

OFFER has allowed RECs to levy a sum of £1 per customer per year over the franchise period to 1998. This resulted in approximately £100 million being distributed amongst the supply businesses of the RECs in order to implement energy efficiency schemes and explore the potential for DSM schemes (152). The expenditure is appraised and approved by the Energy Savings Trust under the Standards of Performance.

In addition to the above the DGES also reduced the revenue driver on the supply business from being 100% related to the volume of kWh sold to 25%. The remaining 75% of the revenue driver is linked to the number of customers and a constant term. The impact of this change on the incentive to either grow or reduce load is minimal when considering the extremely low profit margin on supply that exists.

The indirect effects of the working of OFFER on DSM are seen in the nature of the competitive market place for electricity supply. The competitive supply contract market, that is those customers with a demand in excess of 100kW, poses problems for the RECs when they are considering DSM program implementation. The largest customers represent an ideal opportunity for the RECs when they are pursuing a DSM program with the aim of reducing peak demand on the system, deferring network reinforcement.

The reasoning behind this is that the marketing costs of the DSM program are considerably lower than if, for example, a large number of domestic customers needed to be captured to achieve equivalent load reduction. Also, the costs associated with the validation of savings could be considerably less, and the general control of the program could be more disciplined. However, these customers are in the *competitive* market, a market that is, at present, very much price driven (128). As a result these customers are wary of committing themselves to long-term contracts. This is reflected by the fact that contracting at present typically lasts for two years at most, with one year being the norm (128).

A method to overcome this customer reluctance to commit to long-term contracts is offered through the concept of Energy Services. There are many opportunities for RECs to become energy service providers. Customers don't make all of the economically viable energy efficient investments open to them for many reasons. These are discussed and explored in detail in future chapters and include ignorance, lack of management time, capital shortage, uncertainty of payback, and lack of expertise. RECs are in a position where they can overcome these barriers and gain financially through extracting a percentage of the cost savings. This also has the effect of helping the customer exert downward pressure on energy costs, ultimately improving the customer's long-term future.

Within the franchise market RECs primarily serve domestic customers. It is possible that the same approach could apply in this market. This could be achieved through the provision of energy contracts which provide insulation and kWh's to organisation such as Housing Associations in tower blocks etc. Such a strategy could contribute effectively towards load defence against second-tier suppliers when this market opens up to competition in 1998.

Furthermore, the offering of energy services by the supply business need not be done in isolation to the distribution business. Energy Service schemes could be offered to the customer and then tailored to maximise the benefits to the local network. Thus energy services offer the prospect of unlocking savings for the REC business further up the supply chain.

Generation

The UK has, at present, a dwindling surplus of generation capacity (88). On this basis the scope for promoting DSM for the deferral of investment in generation capacity is unfounded. Additionally, the reduction of load via baseload energy efficiency measures can cost generators an average of 2.5p per unit, the average annual pool price. This cost is at a maximum if technologies are targeted at a local peak demand which corresponds to the system peak demand, as system peak demand corresponds with peak pool price. On this basis, with inherent over-capacity there is little reason for the generators to pursue any form of DSM that reduces load.

The relative volatility of the pool price can also cause problems with the assessment of DSM programs. As stated, pool price can be very volatile, especially at times of peak demand when the marginal supply of electricity is that reduced by a DSM program for deferral of reinforcement. As such, any program involving a shared savings approach with the customer can involve fluctuations in the amount of savings available for extraction by the Supplier.

The relatively low cost of generated electricity has the effect of undermining the viability of DSM to reduce the requirement for generation capacity. DSM programs compete with the avoided costs of electricity supply, of which electricity generation costs represent on average 65% of total cost. There have been many calls for the cost of externalities, such as pollution, to be included in the generation price of electricity. This would undoubtedly make energy efficiency and DSM more attractive but arguments remain as to the appropriate figure to place on these costs and, further, as to whether they are appropriate.

At present OFFER has no such plans to introduce external costs to generation, believing that such issues are a matter of fiscal policy and beyond its remit (151). However, in the future potential EC legislation on matters such as Integrated Resource Planning could force the UK into considering these costs.

The uncertainty associated with the long-term planning environment of the generation market could itself provide an impetus for DSM and the associated area of energy services. Investments in power plants usually take between fifteen and twenty years to amortise. However, the current market where short-term contracts are the norm and the pool is open to regulatory manipulation could conspire to make the market a risky proposition. The obligation on the two major generators to sell 6000MW of mid-merit operating stations could have the unwelcome effect of increasing competition in the pool, particularly if these new operators have little long-term contract cover. This in itself would cause severe revenue fluctuations for generators and force strict financial criteria on future generation investment. The long-term effects of this problem have been suggested as posing severe questions as to whether the pool will be able to secure marginal generation to enable the 'lights to be kept on' (23).

Thus DSM and energy services may, over the long-term, become important in this respect as they offer the prospect of the generators being able to secure long-term supply contracts that will enable maximisation of return on assets.

CHAPTER 5

THE POTENTIAL ROLE OF DSM IN THE UK ELECTRICITY INDUSTRY

Introduction

As discussed previously in Chapter 4, during the period in which the UK electricity industry was nationalised the Central Electricity Generating Board traditionally promoted unconstrained demand by the customers which it served. The basis of this strategy was that the necessary costs for infrastructure expansion could be met through increases in tariffs, and hence, revenues. Due to the principles of averaging implicit in tariff design, even if load growth associated with the expansion did not materialise the CEGB was relatively safe in the knowledge that it could pass on any costs over a large customer base. It was the freedom of planning and investing in supply side investments that led to the potential for what has become known as the '*gold-plating*' of network assets (9, 27).

The arena of privatisation in which the UK electricity industry now operates allows no room for the approach taken during nationalisation. Each area of the electricity industry supply chain is now accountable to shareholders, and investments in new assets must be carried out with the intention of increasing shareholder wealth. As such, investment in new assets requires a more cautious approach than was previously required. Each investment appraisal requires vast amounts of detailed and highly accurate information concerning aspects of, for example, future changes in load growth, electricity prices, fuel prices etc.

The need to obtain information such as that detailed above has caused many companies within the electricity industry to re-assess their utilisation of Information Technology (IT). Indeed, many RECs have invested large sums of capital in developing IT in order to assist with the management of network assets and other areas of their business. Midlands Electricity plc have, for example, spent over £50m on the development of a Global Information System (GIS) which allows them to record real-time data on the operations of their network assets at a highly detailed level. The information and data provided by such systems will, over time, be of great value to any attempts to optimise network assets.

The ability to accurately predict changes in load growth will be essential to each area of the electricity supply chain.

It is the flexibility of DSM investments that will allow players within the electricity industry to optimise the timing of investment in fixed assets. The potential role of DSM in each of the recognised areas of a REC will be discussed in the following pages.

UK Electricity Industry Structure

The UK electricity industry, prior to privatisation, was a vertically integrated business. The CEGB existed in England and Wales, responsible for generation and transmission, whilst Area Boards performed the functions of distribution and supply. In Scotland two companies existed with the purpose of carrying out the entire process from generation to supply.

Since privatisation the UK electricity industry has undergone a transformation into, essentially, disintegrated businesses. Generation is now carried out by 56 different private companies, on both solo and joint investments (126). The responsibility for the transmission system has passed into the hands of a separate company, the National Grid. Distribution, a natural monopoly in the same way as transmission, has been made the responsibility of the twelve RECs. The RECs also operate a supply business which has been progressively opened up to competition since privatisation. In addition to the RECs, other players known as Second Tier Suppliers also operate in the competitive supply markets.

Privatisation - The Removal of the Integrated Business

The vertical disintegration of large capital intensive industries is not peculiar to the UK electricity industry. Jennings (118) notes that in the 1970's United States oil companies were highly vertically integrated from exploration to forecourt petrol pumps. The oil industry was managed to give optimum process efficiency through strong vertical linkages between operating units.

The US oil industry, in response to political and market turbulence during the 1970's energy crisis, was forced to re-examine its structure and this brought about its rapid break-up into operational areas. As such, business portfolios of operation were developed, with exploration, transportation, refining, distribution, and sales each being a separately accountable business unit.

However, Jennings (118) further noted that the US oil companies have gone through a process of horizontal re-integration around the end-use consumer in an attempt to exploit synergies between business units. This is clearly seen in the operations of petrol forecourt divisions which have been seen to diversify heavily into grocery retailing. This process has enabled petrol companies to create new business areas which are profitable in their own right. In addition to this oil companies are now keenly aware of the value of long term customer relationships, establishing energy services companies which are able to not only sell energy but advise the customer as to its optimum utilisation. The UK electricity industry now has the same opportunity to re-integrate horizontally around the customer.

The Role of DSM in the Competitive Markets

Business management models can be utilised successfully in order to demonstrate the operating environment of the UK electricity supply industry. One such model, Porter's '5 Competitive Forces Model', enables the UK electricity industry to be examined as displayed in Figure 5.1. Porter's model displays the five competitive pressures that can operate on a business. These pressures are: suppliers, buyers, substitutes, new entrants, existing competitors.

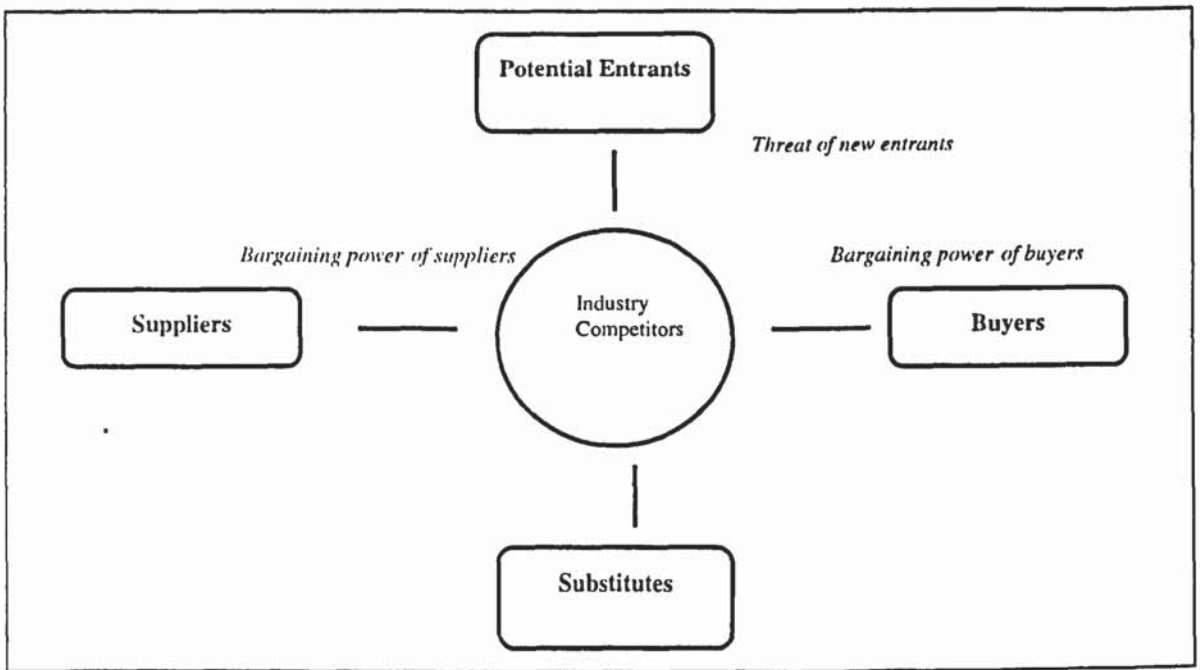

Figure 5.1 : The Five Forces Model of the Electricity Industry (19)

Each of the five areas of competitive forces can be considered in turn:

- **Substitutes** - Substitutes refers to competing fuels such as gas and oil. The main threat here is for services such as heating. Others are renewables such as solar power and cogeneration.
- **Buyers** - Buyer power through flexibility to switch supplier quickly and at minimal cost provides buyers with considerable market power. This power is increased if individual buyers purchase as a collective unit in bulk. This is compounded by REC obligation to supply and the lack of product differentiation at present.
- **New Entrants** - New players are entering, or are planning to enter, the liberalised energy markets. Superstores and Trade Unions (TUC) are examples of organisations with large customer bases which pose a threat to established suppliers. Other aspects are RECs moving into supply and generators entering supply.
- **Suppliers** - Refers to the bargaining power of generators and providers of primary fuels such as oil and gas for power stations. Also, from the suppliers perspective, the power arising from the lack of a substitute product in certain applications.

- **Industry Competition** - The industry is characterised by strong competition in the open markets, slow growth in demand, and evenly matched competitors. Areas not open to competition, and to an extent those that are, are subject to varying degrees of regulation.

(19)

DSM offers the supply businesses of electricity utilities the opportunity to address some of these competitive pressures. The interaction of DSM with the competitive environment of the electricity industry is considered below.

<u>Regional Electricity Companies and DSM</u>

Supply

Post 1998 competition in the Supply market will become increasingly challenging for those companies who facilitate the purchasing and selling of electricity to the end-user. These companies will not only consist of RECs but will also consist of companies known as Second Tier suppliers who are able to purchase and sell electricity with the basic essentials of office space, a PC, and a modem. Along with this increasing number of players within the supply market will come the side-effects of commodity competition, namely reduced prices, reduced profit margins, increased pressure on cost cutting, and increased pressure to explore methods through which to escape price based competition (19). It is the last of these factors which will test the ability of RECs to market the product of electricity in a manner which can persuade the customer to pay a premium price. A premium price for a product which has traditionally been of commodity value, with little product differentiation.

At present the REC supply business has little incentive to increase load within the franchise market, the volume driver being reduced to 25% of allowed revenue. Additionally, it is difficult to see how the supply business could effectively target load growth in a competitive market in which it is using lowest price as a tool for gaining market share. It is widely accepted within the industry that the costs of increasing electricity sales through marketing are not justifiable in terms of the extra revenue received for sales growth. In addition to this the supply business of many RECs, although contributing on average over 75% to total turnover, has very small profit margins of around 1% and can contribute as little as 4% to total REC profit. With such a small contribution to profit that supply represents it would not be unreasonable for a REC to consider focusing entirely on excelling as a distribution business.

At present competition within the electricity supply business is focused upon price, with many doubting the willingness of customers to pay a price premium on electricity in return for energy services (128). Initially many, utilities have competed aggressively within the competitive market in order to win customers and based their strategies on supplying the lowest cost product. Aggressive pricing policies are still a feature of the competitive market as suppliers attempt to remain cost competitive in what is a volatile and complex market.

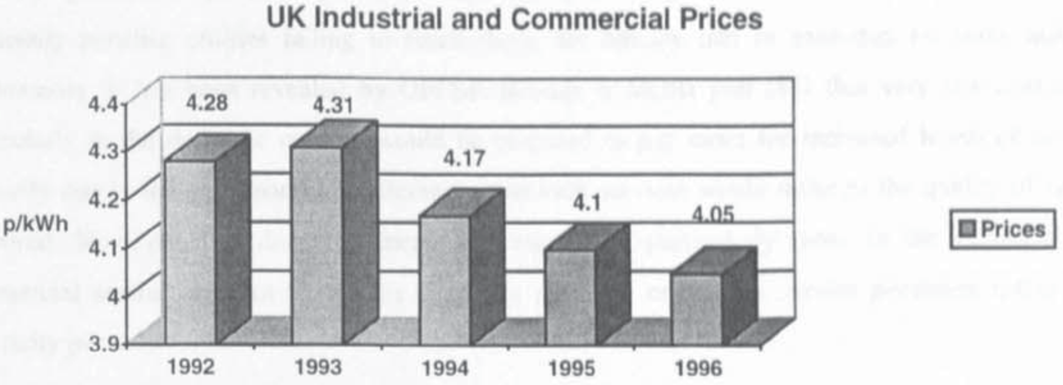

Figure 5.2 : UK Average Industrial Electricity Prices (128)

However Figure 5.2 reflects the fact that annual electricity prices are now beginning to move away from the aggressive price cuts of 1994 and return to a stage where the future will see average prices begin to rise year on year in response to a forecast increase in generation prices. Within this scenario it may be that by the onset of the fully competitive supply market in 1998 customers will be more responsive to EE as the costs of electricity rise at a rate close to, or above, the rate of inflation (128).

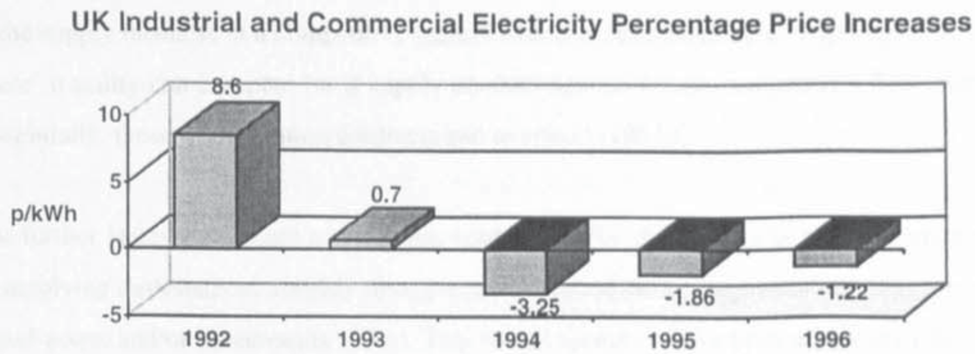

Figure 5.3 : UK Industrial and Commercial Electricity Percentage Price Increases. (128)

Figure 5.3 reflects the trend of electricity prices which are drifting back to levels which could well rise above inflation in the near term. As such, in a market environment where electricity prices are seen to increase above the rate of inflation, utilities may be advised to seize the moment as an the opportunity to differentiate their service offerings.

The utility business of electricity supply can be seen as analogy of the services provided by the financial markets, such as those supplied by credit card companies. It has been estimated in these markets that an increase in customer retention rates of a mere 5% more customers can lead to a 125% increase in profitability (118). Thus the strategic focus of utilities should be on locking in customers to contracts. As such utilities can use differentiation of their product in order to achieve such a result. It has been suggested (118) that this could be achieved by increasing customer service. However, utilities already have high levels of customer service required of them, placed upon them by regulatory control through both the guaranteed performance levels and standards of performance. These standards, which financially penalise utilities failing to reach them, are already met or exceeded by many utilities. Furthermore, it has been revealed by OFFER through a MORI poll (88) that very few customers, particularly in the domestic market, would be prepared to pay more for increased levels of service, primarily due to the very marginal differences that such services would make to the quality of supply delivered. However, this does not mean that customers, particularly those in the industrial and commercial sector, will not be willing to pay a premium on *energy service provision* rather than electricity per se.

It is suggested that within the fully competitive markets utilities will soon arrive at the conclusion that it is not so much the internal costs of the supply business that dictate profits, but competitors prices (80.b). This view is formed on the basis that although the control of the internal costs of the supply business are important they will increasingly take a back-seat when compared to competitors prices. This, it is suggested, will occur as a result of customer segmentation at an increasingly disaggregated level of analysis. This is reflected by the fact that within a tariff system, with associated levels of standard charge, there will always be winners and losers. As a result there will be a paradigm shift away from a minimal number of tariff offerings. This will occur as utilities try to meet their customers' energy needs, at prices which they are willing to pay, and at which their competitors are offering. The internal costs of the supply business in a competitive market will, it is suggested, be an important dictator of 'if' and 'where' a utility can compete for a supply contract against fellow competitors. The internal costs being, essentially, those of generation contracts and overheads (80.b).

Sioshansi further states that where a utility has read the market badly, or has not fully understood the costs of supplying customers at a highly disaggregated level of market segmentation, then the result will be stranded assets and/or investments (80.b). This would appear to have been a feature of the unfolding competitive market in the UK thus far, reflected by supply companies panic selling surplus electricity at heavily discounted prices in a market where well informed customers can receive substantial benefits (118). The upside of this situation is that it will be those utilities that are able to segment the market in an efficient and highly disaggregated manner that should be able to increase market share and maximise returns to the supply business.

However, when considering the proposed scenario there will by implication be a requirement for a high level of product branding and advertising. Attempts to raise the profile of supply businesses has recently been occurring within the utility sector, e.g. the 'Powerline' brand marketing of the MEB supply business. The provision of energy services will form a significant part of utility attempts to segment the market and provide differentiated service offerings through the raised profile of branding and advertising. Already there are attempts to offer *green power*, electricity from renewable energy sources, by potential second tier suppliers such as the *green electron company (118)*. On an equivalent scale there will potentially be room for suppliers who can tailor products to various sectors of industry and commerce, leading to concepts such as, for example, ***Leisure Power.*** Such a concept is reflected through the fact that it has been estimated that up to 20% of the energy usage within the UK could be more cost effectively replaced by energy efficiency measures which reduce demand (17).

The introduction of such facets into supply competition will ultimately erode previous franchise areas. As such, the segmentation of customers in the manner set out above will lead to opportunities for the utility to exploit the most profitable customer groups. The integration of energy services into supply contracts will enable utilities to achieve higher profit margins in certain segments than in others. This fact is not lost on other competitive markets. For example, in car manufacture the market segment with the highest profit margin is that associated with the more luxurious end of the market. For example, BMW make a profit of 50% on the luxury model 700 Series compared to the 30% profit margin on the 300 Series models at the lower end of their market (80.b).

The concept of increased segmentation of customers will inevitably lead to utilities recognising that it is more profitable to serve certain customers rather than others and, ultimately, that some segments are very marginally profitable, if at all. In order to address this issues it is suggested that utilities will have one of two options (80.b):

1. **Cost Adjustment**

Under this option the utility must decide whether it is expensive to serve a particular customer due to the high levels of electricity demand the customer makes at the time of system peak. If the tariff that this customer is on implies a high level of cross-subsidisation by other customers then the utility may be forced to come to an alternative arrangement. This will entail reducing the costs of serving that particular customer through methods such as load curtailment.

2. **Revenue Adjustment**

This option entails placing the customer on a new tariff at a higher rate in response to its reluctance, or inability, to reduce costs of service through other means. Ultimately this may mean that the customer is taken by competitors but this should be of no consequence to the utility as increasingly disaggregated customer segmentation will leave little room for unprofitable customers.

In response to the above it is likely that the effects of increasing tariffs through the greater reflection of marginal cost will be undesirable for political and social reasons. For instance, it would be undesirable if, within the domestic supply market, marginal costing was implemented to the extent that the true costs of serving an isolated domestic dwelling were charged. Essentially, low cost suppliers will have greater room for maneuver on pricing and therefore the winning of customers than high cost suppliers who may, eventually, be squeezed from the market place.

As stated previously, profits on the supply business are minimal at present. However, such small margins are not uncommon in a commodity product business and the challenge essentially becomes one of formulating a strategy to increase profit margins. In order to do so it is possible to adopt several strategies (19):

1. Increase Volume

By increasing the sales volumes of a product it would be possible to take advantage of economies of scale, distributing costs over an increased number of units sold, and therefore reducing the unit price. Due to the presence of tight volume controls to the end of 1998 and the future prospect of a competitive market it is unlikely that such an approach could be successful if based on marketing increased sales. In addition to this, winning market share from competitors will likely involve selling at below cost which would be open to regulatory challenge. However, such a practice is common in competitive markets as new market entrants attempt to win market share, as seen through Fuji Films price war with Kodak Film (19). Despite this it is unlikely that such a strategy would be sustainable for very long and would require quick and lasting results. An alternative way of increasing market volume is to introduce an additional 'free' benefit to the product, such as a freephone helpline. However, covering the costs of such a service usually relies upon increasing sales and market share. Also, REC supply businesses are already compelled by regulatory obligations to provide particularly high standards of service reflected in the 1998 annual report by OFFER which showed customer complaints against RECs at a record low.

2. Reduce Costs

Cost cutting has been a sustained feature of the REC business since the early days of Privatisation. With the evolution of yardstick price regulation RECs have been vigorously cutting costs in an attempt to drive profit margins upwards. Indeed, internal cost cutting has reached a stage at which the scope for further reductions should prove to be very limited. The prime opportunity for the supply business would now appear to be cost reduction of overheads through strategic alliances with other industries, such as water companies, which also have vast customer databases for billing purposes.

3. Product Differentiation

It could be possible, through the offering of an enhanced product, to actually raise the price of a commodity. As such RECs would be embarking upon a strategy of product differentiation, highlighting the superior qualities and features of its product over that of its rivals. Such an example is seen in the petrol industry where certain suppliers have introduced a value added approach through the addition of engine cleaning detergents to their product. This benefit usually comes at a price premium but there are customers who are prepared to pay the excess price in return for what they perceive as a premium product value. The key is to identify the common needs of large customer groups and then deliver a product that can fulfill these needs. Other opportunities include forming alliances with other commodity retailers such as supermarkets, as seen through Northern Electricity's alliance with Tesco plc.

4. Market Niche

Such a strategy would see utilities focusing upon delivering specialist energy services to a particular market sector e.g. the Leisure Industry. The chosen sectors for niche specialisation would have to attach a high value to energy services, reflected through the price premium which would be demanded for their delivery. On this basis competition would be based on the level of service quality that utilities could deliver.

Distribution

The Distribution business provides the vast majority of REC profits despite the relatively low contribution that it makes to total company revenue. Despite tighter regulation, profit from REC distribution businesses in 1996/7 achieved profit margins of 25-30%. This has been achieved in terms of the distribution business contributing between 25-40% of total company revenue (157).

When considering the above, it becomes clear that the distribution business is one in which greatest returns to profits will be achieved through the effective management of assets. This is achievable through the maximisation of returns on network assets. One of the methods of maximising the return on asset is through the optimisation of the load profile. As such, it is vital that RECs are able to understand what drives the load profiles that are present at various operating levels on their system. This is only achievable through the analysis of customer demand at a highly disaggregated and accurate level. Knowledge of customer loads and the technologies which drive them allow RECs to understand the extent of localised network asset optimisation opportunities. This knowledge allows the REC to understand which loads are flexible with respect to time, which are sub-optimal in terms of efficiency, and the extent of elasticity of demand.

Highly detailed information gathered by the REC can allow mutual benefit for both the REC and the customer as asset utilisation is optimised and DSM measures implemented contribute to increased customer wealth.

DSM can also contribute to the postponement or avoidance of network reinforcement, a form of least cost planning (LCP). This has typically referred to the reduction of peak demands on the network system and has been the overwhelming driver of DSM in the few applications of DSM within the UK. For example, Manweb's project in Holyhead. LCP is implemented on the basis of the cheapest possible way of maintaining electricity distribution to customers at the lowest possible cost, whereby cost is evaluated as the net present value of all project costs, present and future, for all possible network solutions. This form of LCP is seen from the REC perspective only. A REC will not actively seek to optimise the energy efficiency of a customer per se. Reduced sales will equate to reduced revenues under all scenarios unless a deferal of capital investment is so great so as to compensate.

DSM opens many new opportunities for the REC business within both distribution and supply. The implementation of least cost planning into the distribution business can be shown to reveal benefits to both RECs and their customers through the optimisation of network assets. However, there are still regulatory, technical, and institutional barriers to the achievement of this win-win scenario. Various regulatory actions have been suggested as militating against the optimisation of network assets through the leveling of the load curve. An example is seen through the reduction of the volume driver from 100% to 50% in the 1994 regulatory price review. These are explored in Chapter 4. With respect to LCP, there is no requirement on the RECs to produce LCP appraisals showing the consideration of the alternatives of demand side and supply side investment.

In an arena where cost savings are all important, DSM also provides a tool for the deferral of network investment. Such deferral not only provides the opportunity of cost savings over a projected timescale, but also has value in terms of its non-committal nature, allowing RECs greater time to assess the true nature of load growth and hence adding to the avoidance of stranded investments.

The supply business can also benefit from DSM. The provision of energy services resulting from DSM programs allows RECs to tap into new business areas, offering the potential for increased profits. The ability to sell energy services will be a pre-requisite for successful DSM, particularly in the industrial sector. It could prove difficult for RECs to recover the costs of a DSM program, within a regulatory framework through an increase in DUoS tariff to the industrial sector, even if it were to facilitate the deferral of network investment. This is due to the cross-subsidisation of cutomers involved within such implementation of DSM. This cross-fertilisation of business areas could be made more difficult if the regulator's proposed changes to the REC business, i.e. separation of supply and distribution, are carried out. These proposals have been discussed in Chapter 4.

The equity issues surrounding the subsidisation or no-cost provision of electro-technologies, which can ultimately serve to increase an industrial customer's competitiveness at the expense of that customer's rivals, are great. It could therefore be essential to sell any DSM technology to the customer, the feasibility of which is enhanced through the ability to provide the finance through an electricity supply contract.

On the basis of the above, it will be important for RECs to retain both distribution and supply businesses. Supply offers the face to face contact with customers that is essential for the building of new business areas such as energy services. Also, supply offers a route towards the greater control of load for the utilisation and optimisation of network assets. However, under present regulatory proposals it is unclear as to whether or not supply will, in the future, be able to achieve the required degree of cross-fertilisation of knowledge with the distribution business.

Having established the positive impacts that DSM can have on both areas of a REC business, the question becomes one of how best to facilitate the workings of DSM in order to combine distribution and supply strategies. The development of this concept will be the main aim of the following chapters.

CHAPTER 6

INVESTING IN THE DEMAND-SIDE AND THE SUPPLY-SIDE

Introduction

Within the state owned electricity industry there was a relatively high degree of certainty in terms of investment decisions and recovery of costs. Investment was carried out on the basis of an established and guaranteed rate of return (23), with long term planning horizons. As such, infrastructure planners were able to operate in an environment which was relatively risk free and thus allowed a degree of freedom in terms of capital expenditure.

Privatisation has had an adverse impact upon this planning environment in terms of security and stability. Rates of return are no longer guaranteed and investments need to be made with the intention of maximising returns to shareholders. Much of the network assets inherited by companies at the time of privatisation are under utilised in terms of maximisation of revenue returns. This is inherent in any system which has been historically designed to provide maximum security of supply, leading to excess capacity which is deemed necessary in order to safeguard against system and equipment failures. The challenge for economists and planners is how to unlock this excess capacity in order to increase revenue and hence returns to shareholders.

In order to achieve this, electricity companies need to be aware of the costs and benefits of the multitude of investment alternatives available to the historical solution of network upgrade and reinforcement. Alternatives such as embedded generation, load transfer, energy storage, and demand side management need to be identified and fully costed in order to arrive at the optimum investment solution. Such analysis is very difficult, needing to account for varying degrees of risk and revenue impacts on differing business areas of supply, distribution and generation. Additionally, external variables need to be considered, such as regulatory formulae, customer demand patterns, and technology advances or changes.

This chapter will consider the investment option of demand side management. The costs and benefits of performing DSM, and the historical alternative of supply side investment, will be compared. As such, the added investment uncertainty within the privatised industry will be highlighted.

Scenario

For the purposes of this analysis the Net Present Value (NPV) investment appraisal technique will be used. The formula is:

$$NPV = \frac{R_1}{(1+r)} + \frac{R_2}{(1+r)^2} ......+ \frac{Rn}{(1+r)^n}$$

(19)

'R_1' etc refer to the net cash flows in the relevant year and 'r' is the discount rate which takes into account the time value of money and the level of risk associated with the investment. The value of 'r' in the NPV equation at the top of page 84 is taken as the rate of return set by OFFER as a rate suitable for shareholder expectations in a business such as electricity distribution. This value was set at 7.5% in 1994-95 (151).

The revenue income to an electricity company when considering the sale of electricity relates to both distribution and supply. These are:

- **DUoS** - The 'Distribution Use of System' charge is that element which relates to revenue recovered by the distribution business. It is chargeable on every unit of electricity distributed. The amount of DUoS recoverable is capped by the regulator in accordance with the class of unit sold. There are four classes of DUoS, LV1, LV2, LV3, and HV. The price caps vary between distribution company, and each company is allowed considerable freedom in the actual DUoS value by virtue of setting revenue recovery in relation to a standing charge and per unit basis. The average values set by OFFER are:

    LV1 = 1.78 p/kWh (units supplied at peak rate of a 2-rate tariff e.g. Economy 7)
    LV2 = 0.34 p/kWh (units supplied off-peak of 2-Rate tariff e.g Economy7)
    LV3 = 1.43 p/kWh (units supplied on a uniform standard rate tariff)
    HV = 0.48 p/kWh (units supplied at high voltage)

    (150)

    The incremental sales achieved by distribution companies above forecast figures are subject to a revenue driver of fifty per cent. This can significantly influence the financial appeal of increasing unit sales. For example, an off-peak unit in the NORWEB area can be worth as little as 0.12 p/kWh (150).

- **Supply** - For the supply businesses of electricity companies there are again different incentives in accordance with customer type. Within the franchise, predominantly domestic, market there is a volume driver of 25%. As such, an incremental unit sold in this market can be worth as little as 0.1 p/kWh. In the over 100 kW market supply costs represent 0.24 p/kWh on average, falling to 0.05 p/kWh in the over 1 MW market (152).

This appraisal will be based upon a substation with the following characteristics:

- 100% domestic customer loading.
- Residual life 15 years.
- 20 MVA firm capacity.
- 3 % per year load growth, uniform across all time periods.
- Upgrade to 40 MVA, £1 million, 40 yr life.
- Power factor = 1.
- No losses.
- Peak lasts for 2 hrs/dy, 3mnths/yr.

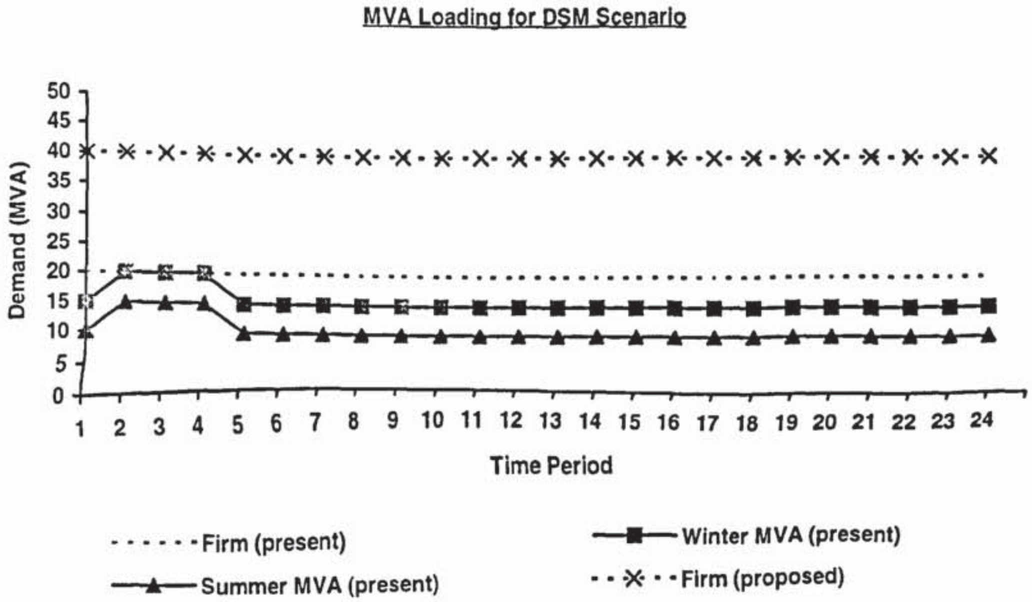

Figure 6.1 : DSM Scenario Transformer Loading

The scenario depicted in Figure 6.1 is one in which a 20 MVA firm capacity transformer is serving a domestic LV1 and LV3 load. The LV3 load refers to an off-peak rate which is part of a multi-rate tariff i.e. Economy 7. LV1 represents the peak rate which is part of the same tariff. The firm capacity of the substation is threatened by the growth of the Winter load peak which occurs for two hours out of every twenty four during a three month period, reducing to the level of the Summer peak at all other times of the year.

The projected growth of 3 % per annum across all time periods produces a demand forecast corresponding to Figure 6.2.

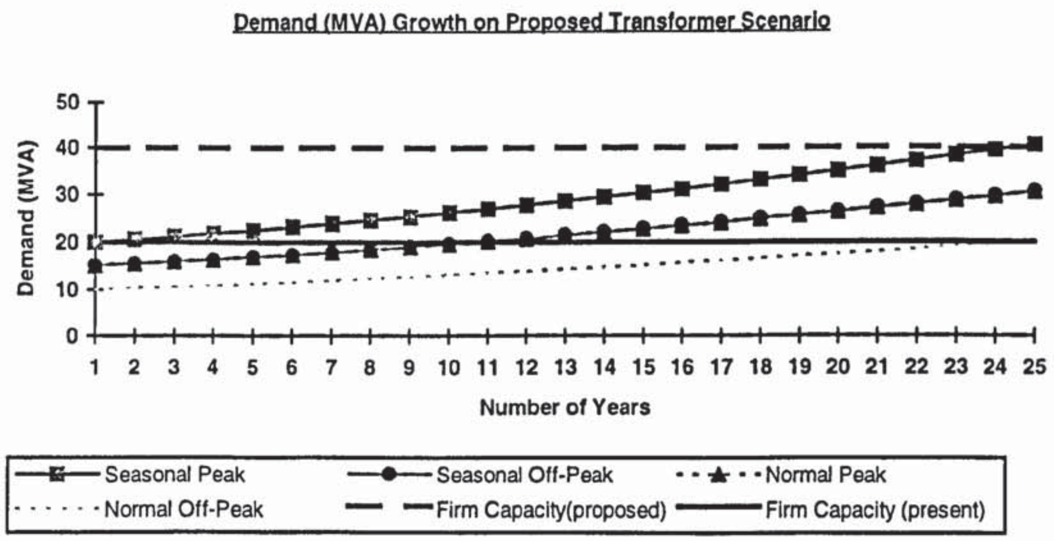

Figure 6.2 : Growth in Demand

Figure 6.2 reveals that the realistic deferral period for the Winter maximum demand is, at most, ten years due to the growth of the Winter off-peak (seasonal off-peak) and Summer peak (normal peak) demands.

A number of scenarios for reinforcement deferral are now considered.

Traditional

When faced with the scenario whereby a substation load is reaching, or exceeding, transformer 'firm-loading' electricity companies have traditionally installed a new transformer pair in order to meet this demand. It has been found that in most cases the new capacity rating would be twice that provided by the redundant pairing on the grounds that incremental capital costs are less influential than installation costs.

The NPV calculation under these circumstances, whereby the substation is uprated at a cost of £1 million in year 1, produces a cashflow and NPV over the ten year period of that shown in Table 6.1.

	1	2	3	4	5	6	7	8	9	10	NPV
MVA Inc.	0	0.6	1.218	1.854	2.510	3.185	3.881	4.597	5.335	6.095	
Standardised Revenue	0	371	753	1147	1553	1971	2401	2844	3301	3771	£10, 741
Capital	(£1 M)	0	0	0	0	0	0	0	0	0	(£930, 232)
NPV After 10 yr.											(£919, 491)

Table 6.1 : Cashflow and NPV over ten year period

The positive cash flow associated with the load which is driving investment is a relatively small sum of just over £10,000 during the previously specified ten year period (ten years deemed the maximum length of potential deferal of investment). Volume drivers have not been associated with this load growth, thus there is the potential for this figure to be overstated. Additionally, the growth beyond the standard 3% will attract the 50% volume driver. As such, the return on the initial investment of £1 million is, in the first ten years, extremely limited.

The picture is brighter if the life-span of the investment is taken into consideration, delivering a NPV of over £18 million. In light of this example, when considering the best possible return to shareholders it is the timing of the investment which becomes crucial.

Winter Peak Load Shifting

Under this scenario, the peak Winter load which is driving reinforcement is reduced year-on-year through the reallocation of demand to other periods outside the peak time yet within the Economy 7 period. Reference to Figure 6.2 provides confirmation that the uniform redistribution of the units beyond firm capacity could be allocated to the E7 load (Note: *the E7 load does begin to slightly exceed firm transformer rating by the end of the ten year period under redistribution*).

The impact on distribution revenue of this option is neutral. Units shifted from the peak to within the Economy 7 time frame are subject to the same unit rate. As the number of units is not reduced then the impact is negligible. This ten year deferral of capital investment provides a NPV of over £445,000. As such, it is possible to spend up to 8.35p/kWh on load shifting measures to defer investment.

A further benefit of the redistribution of peak units to off-peak E7 times is that the substation life time is extended by ten years. This is because the altered demand in twenty five years time compares to that projected at fifteen years through traditional reinforcement. The revenue stream associated with this extra ten years of income is estimated at over £10 million.

Energy Efficiency

When considering the utilisation of energy efficiency measures as a tool of DSM there are three sub-groups:

- Unfocused Energy Efficiency - energy efficiency measures are utilised which affect loadings outside the time period of the substation peak. These measures are a last resort option, leading to lower distribution revenues than necessary.

- Seasonal Energy Efficiency - energy efficiency measures are utilised in accordance with the seasonal nature of a peak load. For example, cycling air conditioners during Summer peaks, fitting insulation to houses to lower E7 space heating loads and thus reduce Winter peaks.

- Targeted Energy Efficiency - these energy efficiency measures will focus upon those technologies which operate only within the peak load time scale at the appropriate time of year.

Each case is analysed below.

Targeted Energy Efficiency

It is assumed that the higher efficiency technologies employed to reduce peak demand target the two hour peak-demand period only. As such, distribution revenue is lost to reduced sales at that time. This results in a loss of approximately a NPV of approximately £5,000. When subtracting this sum from the NPV of deferred investment a refined NPV of approximately £435,000 is achieved on capital investment. As such, energy efficiency measures of under 8 p/kWh would provide a net saving on the traditional reinforcement scenario.

The lost revenue is reduced to half of the original DUoS due to the 50% volume driver on distribution units sold.

Seasonal Energy Efficiency

In this scenario the energy efficiency technologies employed would provide load reduction across all time periods in the appropriate season. It is assumed in this example that the Winter season will occur for ninety one days of the year.

On the basis of the assumptions made, the loss of revenue over the ten year period equates to approximately £257,400. On a NPV basis this equates to a ten year NPV of £188,000. This would enable spending per kWh reduction to be at an upper limit of approximately 3.48 p/kWh.

Unfocused Energy Efficiency

Load reduction equivalent to that required to reduce the seasonal peak would occur for twenty four hours per day throughout the year.

On the basis of the assumptions made, the reduction in DUoS revenue provide a negative NPV of £772.2, an overall NPV of minus £327,000 when deferral of network expenditure is considered. On this basis, it is clearly not worthwhile applying DSM as the lost revenue from energy efficiency exceeds the potential savings on the deferral of capital expenditure for reinforcement.

It is evident that when considering DSM as a means of deferring network expenditure it is essential to assess the likely impact of the technologies utilised on DUoS revenues. As such, technologies must be identified in terms of the timings of operation on an hourly and seasonal basis. Table 6.2 provides details of the range of possible outcomes of the considered DSM scenarios.

	10 yr NPV	Investment NPV	DSM Cost p/kWh
Reinforcement	(£919, 491)	£223,509	/
Load Shifting (E7)	£445,000	£668,509*	8.35
Targeted Energy Efficiency	£435,000	£658,509*	8.00
Seasonal Energy Efficiency	£188,000	£411,509*	3.45
Unfocused Energy Efficiency	(£327,000)	(£103,491)	/

*Assumes EE Measures Become Non-Operational After Year 10

Table 6.2 : Comparative Revenue Streams For DSM and Reinforcement Scenarios

The impact of DSM programmes on revenue streams due to fluctuation in DUoS payments is quite considerable, and variable. The analysis is simplified to minimise complexity and assist in data handling, and thus may overstate some NPV values. This is seen through the example of unfocused energy efficiency as the calculation was based upon continuous operation of a technology.

However, the calculations do provide an insight into the differing impacts of certain DSM options. In addition to this, an analysis can be made of the differences between DSM options and highlights areas of concern. For example, the calculations show the importance of being able to target load reduction or load shifting in order to maximise DSM programme revenues. This in turn leads to the recognition that in order to do so electricity companies must be aware of the electrical loads being drawn by the various customers who represent the substation profile. In order to achieve this level of understanding electricity companies will need to become aware of the needs of their customers, in terms of end-use technology utilisation and the social/commercial drivers of these technologies.

Such a concept is delivered in Chapters 8 to 12, which explore the possibilities and potential for such an approach within the industrial sectors, specifically the sanitaryware sector.

CHAPTER 7

THE APPLICATION OF DSM BY INDUSTRIAL SUB-SECTOR

Introduction

It is proposed here that a more effective means of applying DSM to the industrial sector would be achievable through assessing industry by sub-sector. Such an approach would allow those who plan DSM programmes to obtain an immediate and accurate insight into electricity demand and consumption at a device and process level.

It is believed that on an aggregated level the scope for the planning and implementation of DSM within the industrial sector suffers from being too haphazard, with utilities requiring a greater and more detailed knowledge of the electricity utilisation of specific customers. As such, DSM when applied in a 'blanket' manner, as is currently done in the UK, is potentially removed from the optimum result for both customer and utility. Additionally, it is believed that the framework presented here will provide greater opportunity for the Supply and Distribution businesses of RECs to integrate information and enhance benefits for the REC as a whole.

The construction of a framework for the implementation of DSM by industrial sub-sector is developed over the following pages. The application of the framework will provide detailed information on the chosen subsector. The information will include detailed analysis of the sub-sector's business environment, process techniques, technology trends, and end-use technology utilisation of electricity. This information will allow the construction of a comprehensive industrial DSM program, providing an insight into energy services opportunities which further provide opportunities for long term contracts and the optimised utilisation of network assets.

Applying DSM by Industrial Subsector

At present there is no recognised planning framework in the UK for the purpose of practising DSM by industrial sub-sector. The prevailing approach at present is to practise DSM on an industry wide basis using a blanket approach. It is thought that by tailoring DSM to the specific needs of industrial customers that more positive participation levels could be achieved. This in turn would lead to a higher probability of programme success, retaining less risk, and would provide an opportunity for the Supply business to obtain long-term contracts.

The electricity market within the UK is gradually approaching the stage where the market will be mature enough to start exploiting the opportunities to increase margins on the supply business through energy services. Product differentiation that exists between suppliers is seen on a price basis and is generally very minimal (118), with all RECs having similar cost profiles. The area of energy services provision offers an opportunity for RECs to escape from the restrictions of regulation and thereby enhance profitability. The nature of sub-sectoral industrial DSM would provide RECs with the information required to identify such energy services opportunities whilst allowing them to be assessed in the light of any localised network strategies.

Another problem associated with the implementation of industrial DSM through a blanket approach is that it is unable to adequately compare and consider the wide variations in energy usage, on both a timing and magnitude basis, between industrial sectors. This type of planning is sub-optimal in terms of providing a preliminary decision on whether or not a demand side measure should take preference over a supply side measure as derived calculations could produce large inaccuracies. Generic technologies such as High Efficiency Motors (HEM's) are not ruled out using the sectoral approach. Rather there is a recognition that HEM's as an energy efficiency measure to target peak reduction, for example, are not necessarily cost-effective for all sectors. This is reinforced in Chapter 2 which considers the US experience of DSM where prescriptive DSM programs utilising HEMs suffered lower participation rates and were less cost-effective than custom DSM measures. Table 7.1 highlights the fundamental differences between sub-sector and blanket industrial DSM.

Focus	Sectoral DSM	Blanket DSM
Customer	Allows REC to obtain a greater understanding of customer needs. Builds customer confidence and therefore has implications for program participation.	Allows no real understanding of customer needs. Shows superficial understanding. Customers may become wary of REC intentions. May adversely affect program participation.
Load Profiling	Customised Load Profiling. More realistic idea of industrial DSM potential. Separate industries have separate DSM potential due to processes, working patterns etc. Sectoral approach minimises this problem.	Generalised Load Profiling. Less accurate. Estimates fail to take into account the variation between sectors in terms of process, efficiency etc.
Energy Services	Allows the creation of an assessment of the Energy Services potential within the sector. Provides safeguard against a changing competitive environment. Allows expansion into unregulated profit areas.	Approach is short term on a future competitive basis. Allows no formulation of potential for Energy Services within a particular industry.
Load Management	Approach allows the sub-sector to be assessed for load management potential through addressing working patterns and processes.	Difficult to ascertain the potential for load management due to lack of information on the working patterns and processes of industry types.
Load Defence	Formation of Energy Services knowledge allows REC to assist customer with cost control, improving efficiency and therefore increasing competitiveness. Has the effect of stabilising business base. Addressing industrial sectors allows targeting of those in most need.	No prospects for formulating a planned defence mechanism. Hit and miss basis, increased customer stability/competitiveness is seen as a bonus, not a goal.
DSM Implementation	Allows RECs to offer the most suitable DSM measure for the particular industry sub-sector. Increases program cost effectiveness.	Approach can lead to mis-directed DSM expenditure as some customers are, unknowingly, unsuitable to DSM proposals.

Table 7.1 - Advantages of Sectoral Industrial DSM Against a Blanket Approach

The requirements for producing a DSM program on a sub-sector basis will be presented in the following pages, allowing the construction of a planning framework to optimise program success.

Industrial Sub-Sector DSM Framework

Many factors will influence the design of a DSM program. These factors include the utilities load shaping objectives, the range of technologies available to the sector, the competitive environment of the sector, the organisational behaviour of the customers selected, the regulatory arena, and technologies already in use by a sector.

A Framework which allows for the assessment and identification of industrial subsectors, suitable for the differing aspects of DSM, is presented in Figure 7.1.

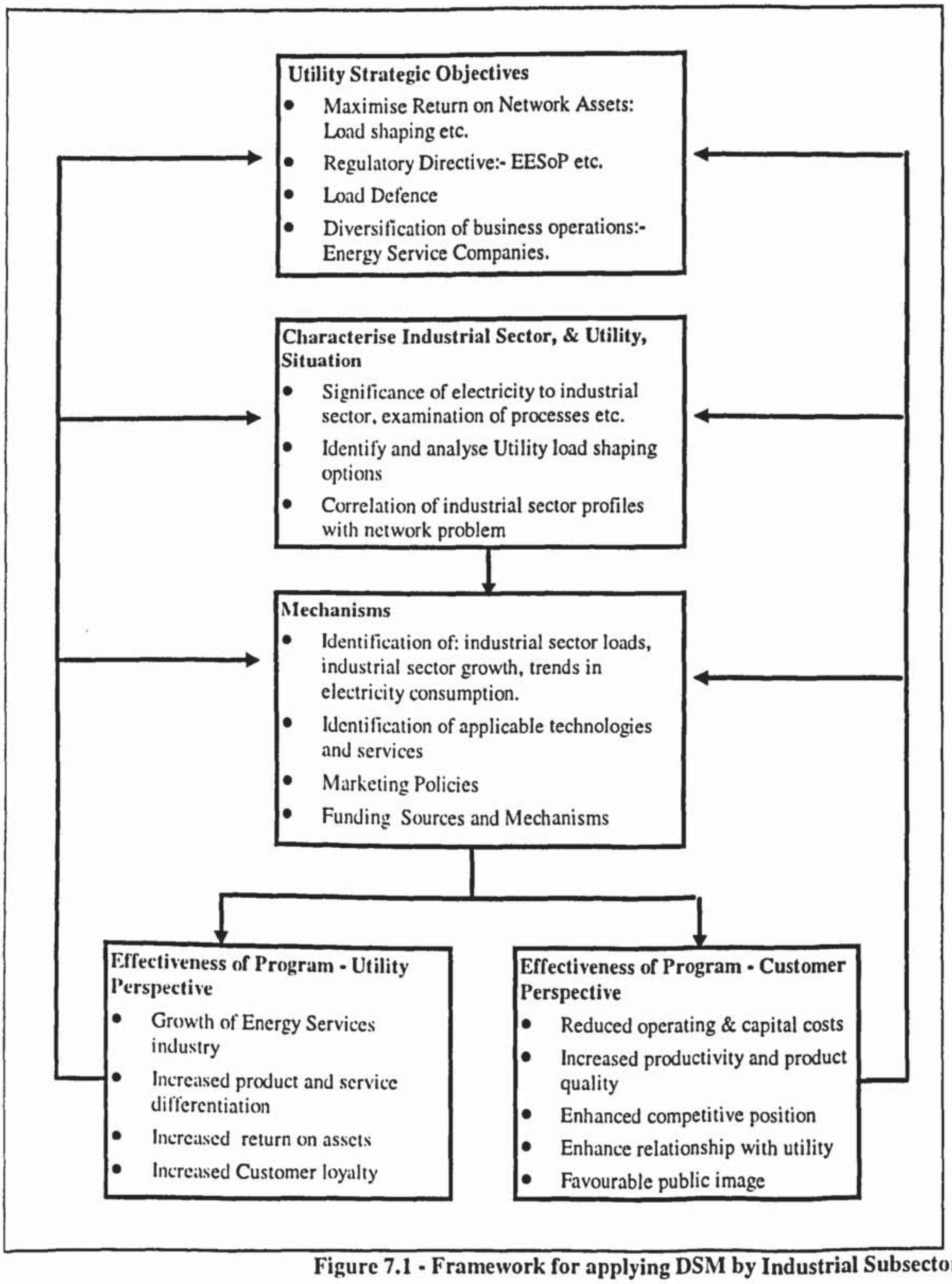

Figure 7.1 - Framework for applying DSM by Industrial Subsector

This framework can be used, for example, when trying to assess the suitability of a particular industrial sub-sector for the purpose of promoting the energy services business or, alternatively, to assess the potential of a sub-sector for the load shaping objective such as peak clipping.

The framework provides a systematic approach to the identification of the characteristics of a particular DSM scenario in relation to a specific industrial sub-sector. The identified characteristics are key to the selection and effectiveness of a particular DSM program mechanism. The mechanism for implementation of the DSM program will vary greatly in its effectiveness depending upon the situation in which it is implemented. The stages presented in Figure 7.1 will now be presented in further detail.

<u>Determination of Utility Strategic Objectives</u>

DSM is by its nature a demanding and integrated process, requiring the participation of utility staff from the various divisions of:

- Strategic planning
- Technology Assistance
- Customer Services
- Market Research
- Load Research
- Tariffs and Pricing
- Communications
- Regulation
- Load Management

The above group will be required to achieve a high level of cross departmental co-operation, remembering that the DSM program design and its successful implementation will only be achieved through this approach.

There needs to be a clear definition of the objectives to be achieved through the implementation of the DSM program. The selection of a DSM program may have the effect of fulfilling several objectives. This refers to the desired outcome of the energy services or DSM programme which is implemented by the utility. These objectives can be to:

- Improve financial performance
- Promote economic development
- Meet need for reliable and economic service
- Improve customer service
- Increase asset utilisation
- Protect customer base

In order for the above to be realised there is a need for the co-ordination of utility long-term planning objectives with short-term operational objectives. For this need to be met there is a requirement for an accurate and detailed information base from which management can select the appropriate short-term action to fulfill long-term objectives.

One of the most important aspects of the Framework is its ability to deliver the identification of Energy Services opportunities which can fulfill the objectives listed above. The deregulation of the UK energy markets, leading to the creation of a highly competitive market for supply contracts, has forced utilities to reconsider the type of relationships which they seek with their customers. Many utilities are becoming 'customer-focused', creating business opportunities around the core theme of customer needs.

As a result of this fundamental shift away from being a monopolistic, commodity selling business, utilities have expended large sums on revamping marketing and sales operations. The small margins associated with the traditional annual round of contract negotiations for energy supply have posed utilities with the problem of how to move away from short-term supply and into longer-term contracts with associated higher margins.

In response the supply businesses of utilities are beginning to offer additional value-added services to energy supply contracts as a means of differentiating their products from those of competitors (141, 153). Central to this is the recognition by utilities that they need to gain a detailed understanding of their customer's uses of energy in order to offer appropriate energy services/supply contracts which benefit both utility and customer. For example, from the customer perspective DSM technologies can reduce operating costs, increase production, improve product quality and improve the working environment for employees. The benefits for customer and utility are portrayed previously in Figure 7.1.

Within the competitive market it is vital that utilities are able to market their supply business under such terms. The traditional basis for the funding of DSM, that is direct rebates on promoted technologies, will be difficult to justify in the competitive market. This will be due to the fact that many DSM technologies can bring productivity improvements as well as cost savings. When considering this it may prove to be difficult to justify making one company more competitive than another via a direct rebate. This problem can be overcome via the provision of energy services whereby the customer pays for the measure out of accrued savings

Characterisation of Industrial Sub-Sector

An overview is required of the sub-sector's competitive position, utilising information on both home and overseas markets. Also an analysis of the electricity intensity of the industry, and an assessment of how the sub-sector relates to a utility's geographical network area, is required. Information required includes:

- **Classification of Sub-Sector :** The initial starting point for this stage would take the form of a Standard Industrial Classification (SIC) code. The industrial sub-sector may itself have sub-sectors within it which justify further disaggregation requiring the move from 3-digit SIC to that of 4-digits. For example, the industrial sub-sector of ceramics has internal sub-sectors of sanitaryware, tableware, tiles, and electrical ceramics. The processes and end-uses within any internal sub-sector need to be assessed in order to determine exactly how far any disaggregation should go for the purposes of load profiling and assessment.

The size of the sub-sector within a utility area should also be assessed in order to determine the ability of any DSM program to deliver localised network benefits. Utility billing records should provide a starting point for obtaining a preliminary indication of energy intensity within the sector and the potential contribution to system peak loading. Obviously, areas which have a high representation of the selected sub-sector will be able to offer greater potential network benefits through DSM than areas of low representation. However, sub-sector customers outside the utility area could themselves be targeted through the DSM assessment, with the utility having a level of knowledge which is detailed enough to enable it to become a specialist in providing energy supply to the particular sub-sector.

- **External Operating Environment :** This stage involves the collection and analysis of data and information on the competitive situation of the sub-sector. The development of a sound knowledge of business and product trends within the sub-sector will help to enable the DSM planner to gauge the likely reaction of the sub-sector to a DSM programme. Information will assist with an assessment of the sub-sectors strength against foreign competition and its present financial status, as such a sub-sector which is struggling could be more likely to accept assistance in controlling energy costs.

  Sources able to provide such information will again come from government publications such as Business Monitor, Keynotes, and monthly production indices. Other sources will include the customers themselves and trade organisations.

- **Production Processes and End-Use Technologies :** When examining industrial customers within the same subsector it is to be expected that common process throughput stages will be found. These process stages will highlight the end-use technologies utilised and therefore allow assessment of the opportunities for DSM technologies.

  This information on processes and end-use technologies can not be considered in isolation. The findings need to be in to the context of other information concerning aspects of operating schedules and equipment utilisation, non-electrical energy usage etc.

- **Electricity Usage and Load Profiles :** Information on the total site loading for a customer within a particular sub-sector should be available through billing data analysis and be sufficient to establish a typical industrial sub-sector site profile.

  In many industries the majority of electricity is consumed by motors. The identification of motor load and the resultant profile of consumption, and also that for other technologies such as lighting, requires the on-site monitoring of production processes and equipment. Where electrical load is not variable with throughput a first-order energy audit can be performed. This can be carried out by monitoring operating times, and taking capacity ratings, of equipment that is highly representative of the process in question. It should be possible to derive a theoretical demand profile. For further sites in the same sector, utilising the same technology, the profile can be scaled in relation to throughput or other physical parameters such as floor space, allowing an estimation of a technology's contribution to site load.

- **Identification of Applicable DSM Technologies :** The identification and implementation of DSM technologies and process changes will primarily relate to the load shaping objectives or the energy services opportunities which are identified by the utility.

  A starting point for the identification for opportunities is the identification of processes that lend themselves most readily to the desired load shape change. For example, within the sanitaryware sector, for load reduction across the majority of the working period it may be reasonable to target lighting load. The next stage is to identify the available technologies for achieving the desired load shape change, such as High Efficiency Lighting.

  Other load shaping objectives are also available to utilities. Load growth can be achieved through fuel substitution or 'electrification', primarily where electricity driven processes can compete with the low cost of fossil fuel by offering enhanced quality and reduced rejection rates. Load shifting is another option whereby processes and technologies can be modified in terms of their time of use, shifting process 'on' times to areas away from the local system peak.

  The construction of a process/technology and DSM objective matrix can be constructed in order to provide easy and readily accessible information to the user.

An assessment also needs to be made of the non-energy benefits of the program for the identified customers in relation to their particular industrial sub-sector. These can include:

- **Environmental Regulations** - electro-technologies can be utilised in order to meet environmental targets or concerns. For example, microwave-assisted firing of ceramics is reported to reduce emissions of carbon dioxide and other pollutants associated with gas. Heat recovery systems also increase efficiency and reduce emissions associated with primary fuel consumption providing process or space heating.

- **Increased Productivity & Reduced Costs** - dependent upon the industry in question, process times can be reduced significantly through the adoption of electro-technologies. As such, throughput rates can increase thereby improving the competitive standing of the industry. Fast fire electric kilns in the tableware industry have been able to reduce firing times from five hours, for the original gas fired kilns, to only twenty minutes. In addition to this, the electric kilns were fully automated, enabling a fifty per cent reduction in required manpower, and a reduction in production losses of fourteen per cent (130).

Market Implementation

This is one of the most important aspects of DSM programme planning. The technologies available to fulfil DSM objectives need to be carefully analysed and assessed as to their technical potential. In addition, careful consideration will need to be given to the method of market introduction and promotion of the technology or service. It is also necessary to establish the manner in which the DSM promotion is to be funded i.e. shared savings, subsidisation etc.

The selection of the DSM or energy services offering will relate to the asset utilisation objectives of the utility. A utility may, for example, desire to increase the utilisation of a particular area of network where considerable capacity is available. Having intimate knowledge of a particular industrial sub-sector's energy utilisation will enable the utility to tailor energy services, and DSM, to match benefits for the customer and the utility.

Mechanisms

This stage of the planning process involves research into the organisational behaviour of the subsector. Customer needs and benefits may very well vary even within a particular sub-sector. A subsector may, for example, be known as one which is innovative and conscientious of energy costs, willing to invest in energy efficiency but, at the same time, could thus prove to be of minimal value to a DSM program focusing on load reduction. This is because the customer is likely to have already invested in the cost-effective energy efficiency opportunities within the site in question, or would be likely to do so. This 'free-riding' effect, whereby customers receive utility assistance in implementing DSM measures which they were likely to carry out themselves anyway needs to be considered in DSM program design.

Behavioral analysis through the use of a questionnaire designed to assess the attitudes of the companies within a particular industry sector will allow assessment of the prevailing needs of the sector relating to energy costs and energy supply. This is explored further in Chapter 11. The outcome of the analysis will enable the utility to devise the appropriate marketing strategy for the sector in question. Options for the implementation of DSM programs include:

1) **Customer Information** - this could be provided in the form of education or advertising about the selected DSM technology. The use of case studies such as Best Practice Programs from the Energy Technology Support Unit (ETSU), demonstration events, seminars etc. all help to make the customer aware of the benefits of DSM.

2) **Financial Incentives** - these can be used to reduce the initial purchase cost of DSM technologies. The incentive can be an interest free loan, shared savings, cash rebate or other form of financing.

3) **Trade Allies** - this primarily describes equipment manufacturers. Utilities can attempt to influence equipment manufacturers to become involved in the promotion of the program, giving an alternative source of information and reassurance to the customer.

4) **Direct Customer Contact** - as a result of research work into customer's load profiles by process and technology type a utility will be in a position to select a sub-sector which offers the best contribution to the obtainment of the DSM objective. The selected customers would each have a sales representative from the utility who could provide the access to the customers site required for auditing and feasibility studies.

(108)

The stages of the framework set out above will assist the utility in the identification of the most suitable DSM program for the sector in question, maximising the chances of program success.

The major benefit of DSM when making a cost-benefit appraisal with the alternative of traditional supply side investment is its modular nature and inherent flexibility. DSM programmes can be modular in implementation, allowing the utility to make minimal investment in order to ascertain the likely success or demand for the programme or energy service.

However, this assessment requires skills of planning, analytical modeling, reliability assessment, and high quality data. Lack of experience in market assessment and customer acceptance analysis are deficiencies which must be overcome if DSM is to be utilised in earnest.

Program Effectiveness

The DSM program can be evaluated within the framework on its ability to satisfy each of the aspects of program effectiveness. The evaluation can then be fed back into the preceding stages of the framework in order to improve the success of future DSM programs.

In order to ascertain the success of the programme when considering network asset utilisation it is necessary to develop a mechanism for quantifying programme impacts. The effect of particular technologies on a network load profile are very difficult to quantify. This is also true even at the disaggregated site level. Many factors influence the demand of an industrial site for energy, in both magnitude and timing respects. Factors such as weather, fuel price, changes in productivity, changes in technology in other areas of the production process, and changes in plant utilisation can all influence energy demands.

It is essential that utilities are able to monitor the effects on energy consumption of any changes in technology that are made by the programme. This is imperative if utilities are to make rapid responses to any short-comings associated with installed measures.

The potential for customer dissatisfaction as a result of lower than anticipated savings on an energy bill is great. The verification of energy savings, taking into account changes in influencing factors such as throughput and weather, is crucial to maintain program integrity. It may well be that energy savings verification needs to be done by an independent third party. This could well have the effect of rendering marginally cost-effective programs redundant. However, it is believed that the sectoral approach hypothesised in Table 7.1 could address the reluctance of customers to trust the utility to undertake savings verification. This is achieved through customer confidence in the utility increasing as the utility shows a greater awareness of the customer's production process and associated issues.

CHAPTER 8

DSM BY INDUSTRIAL SUB-SECTOR: AS APPLIED TO THE CERAMICS SECTOR

Introduction

Chapter 7 provided a famework through which DSM via Energy Services can be applied to a specific sub-sector of industry. In relation to the 'characterisation' and 'mechanisms' stages of Figure 7.1 of Chapter 7, the methodology applied at the subsector level can consist of the following stages:

- **Identification and characterisation of industrial sector**
- **Monitoring and assessment of end use technologies**
- **Analysis and modeling of sector electric demands**
- **Identification of applicable DSM technologies and process changes**
- **Identification of market implementation methods**
- **Evaluation and selection of DSM program**
- **Development of sector DSM plan**

These stages will now be applied to the ceramics industry. The ceramics industry has been chosen on the basis that the sector has a high concentration of manufacturers within the geographical network area of Midlands Electricity plc. On this basis, there is a high probability of a number of ceramics sites being connected to a particular area of distribution network.

The research undertaken in this thesis utilises the UK ceramics manufacturing sector in order to demonstrate the application of stages 2 and 3 in the framework derived in Chapter 7 (see Fig 7.1). Stages 1, 4a and 4b are beyond the scope of this thesis, being dependent upon the application of real adoption of the framework through an active programme.

The application of the framework in terms of assessing similarity of electrical demand across a subsector has focused upon the sanitaryware sector. This subsector of the ceramics industry was selected due to the manageable number of manufacturers within the UK. On this basis it was possible to perform a first order energy audit on all fourteen manufacturing sites. A full monitoring survey utilising electronic monitoring equipment was carried out at one particular site. Auditing was necessary to obtain detailed information on the timing and demand of electricity within the sector as no previous study had been made. The survey also allowed an assessment to be made as to how similar electricity usage, by magnitude and timing of demand, actually is within a particular industry subsector.

Characterisation of Industrial Sector

The ceramics industry is composed of four sectors:

- tiles
- tableware
- sanitaryware
- electrical and other ceramics

Within the UK much of the ceramics industry is sited in the Stoke-on-Trent area of England. Midlands Electricity Plc (MEB), as a result of its geographical status, is therefore faced with the responsibility for providing these many ceramics customers with their electricity. In 1992 the ceramics sector within MEB was estimated to consume approximately 220 MWh of electricity each year (171). This electrical load presents MEB with an opportunity to undertake DSM programs in areas of network stress which may appear in the near future.

Ceramic Manufacturing Energy Consumption Within the MEB Area

A study by ETSU in 1992 (132) estimated that the total sector regional energy consumption to be 7,540 TJ pa of which 780 TJ pa (10% of which is power or 217 GWh pa). It was also estimated that significant part of the total electricity consumption is attributable to tunnel and intermittent kiln firing (31% and 5% respectively). The balance of 140 GWh is assumed to be used in pumping, kiln fans, and making machinery. The results are shown in Table 8.1.

Demand Size	Total Demand (MWh(e))	Number of Customers	Average Unit Size (MWh(e))	Total Electricity Consumption (TJ/y)
0-100kW	4,217.9	42	100.43	15.18
101-1MW	69,314.3	76	912.03	249.53
1MW +	143,503.0	20	7,175.15	516.61
TOTALS	= 217,035.1	= 138		= 781.33

Table 8.1 : Breakdown of Ceramics Customers Within the MEB Region (129)

For the purposes of DSM Table 8.1 reflects the advantages of targeting the smaller number of large customers (1MW+) which have the greatest average unit size. Through the targeting of the largest customers it is predicted that program costs will be lower in terms of administration and incentives, and also that by virtue of their larger peak demands a greater impact could be made on system peak. However, when attempting to target areas of the network peak in order to reduce demand, the figures are of little use, giving no indication of the contribution to system peak of the ceramics sector due to the lack of time-of-use information.

Regional Production Figures For Ceramic Industry Within the MEB Area

In 1992 regional production for the sectors was estimated at 312 ktpa, 54% of the national output (171). Projected levels of output for future years are predicted by the British Ceram Research Organisation using Output Indices and the forecasts at 1992 are shown in Table 8.2.

Output Year	1980	1985	1990	1995	2000
Higher Scenario	96.5 (629)	80.9 (527)	87.2 (568)	97.2 (634)	108.4 (707)
Lower Scenario	96.5 (629)	79.7 (519)	83.8 (546)	90.3 (589)	97.3 (634)

Table 8.2 : Projected Levels of Output from the Pottery Industry and Values (£ at 1980 levels) (103)

The pottery industry slumped after 1980, with outputs falling. In 1981 and 1982 the index levels were 85.5 and 77.4 respectively. It was thought unlikely that by 1985 the pottery industry would reach 1980 levels due to the demanding growth rate of 7.7%/yr which would be required. It was estimated that in order to reach 1980 figures again, even by the year 1997, the industry would have to grow at around 2.8%/yr (103).

Sanitaryware Business Trends

In 1992 the total UK market for sanitaryware was estimated to be worth £799 million. Of this, 80% was attributed to the domestic market, of which 64% was attributed to home improvements and 16% to new housing stock. The remaining 20% of the total market was classed as the commercial market (140).

The industry is heavily dependent upon the construction industry for a large part of its sales. The building slump which began in the late 1980's impacted heavily upon the sanitaryware sector. Between 1988 and 1993 new house starts had fallen by 39% in the private sector and 36% in total. This corresponded with a reduction in the workforce of the major sanitaryware producers of approximately 10% (140).

	1987	1988	1989	1990	1991	1992	1993	1994
UK Sales (£m)	267	316	356	295	290	200	159.0	150.3
Imports (£m)	61	65	75	67	55	40	15.6	20.8
Exports (£m)	50	55	65	83	86	54	28.5	33.7
Apparent UK Market (£m)	278	326	366	279	259	186	146.1	117.6

Table 8.3 : Sales Figures for the UK Sanitaryware Industry 1987-94. 1994 Money Values (140)

Table 8.3 supports the notion that the sanitaryware sector is closely correlated with the construction sector in terms of success. Before the slump in the housing market impacted upon the sanitaryware sector at the end of 1989, the value of UK manufacturers' sales were at a high of £356 million. The sanitaryware sector experienced a boom period in the early 1980s, following a corresponding housing boom and an increased demand for co-ordinated bathroom suites (140). However, by the middle of the housing slump in 1991 this had fallen to £290 million. It is widely acknowledged by the sector that the impacts of this housing slump were cushioned by increased sales overseas, both within Europe and to Africa. The fall in imports also reflects the housing slump and to some extent shows that the UK industry is a strong performer on a global scale, with exports exceeding imports from 1990 onwards due to aggressive selling in the face of a reduced home market (105).

The sanitaryware industry is dominated by Armitage Shanks who represented 70-80% of the market by sales value in 1991, and headed the retail market with 23% of sales volume in the same year. The other large manufacturers of sanitaryware are Caradon Twyfords with 20% of the retail market, Ideal Standard and Spring Ram (140). Within the MEB region sanitaryware production accounted for almost 80% of total UK manufacture, containing 11 of the 14 manufacturing sites of Great Britain.

In a survey carried out in 1993 there was a growing belief that a sales upturn was imminent (140). Many manufacturers suspected that their future long term goals were to try and survive in an increasingly competitive market, which UK companies would dominate, and also to increase profitability through improving processes and working schedules.

<u>**Tiles Sector Business Trends**</u>

The manufacture of tiles in the UK is restricted to a few companies and is relatively small scale when compared to Europe (130). The two major UK companies are H & R Johnson and Pilkington Tiles, the former producing 60-70% of UK output. Both are within MEB's distribution network. Production levels from 1987-91 are shown in Table 8.4 (140).

	1987	**1988**	**1989**	**1990**	**1991**
Unglazed ('000's m^2)	2500	2600	2650	2600	2550
Glazed ('000's m^2)	18000	16000	13500	12500	12000
Total ('000's m^2)	20500	19200	16150	15100	14550

Table 8.4 : Production in '000's Square meters (140)

The general trend in tile production has been downwards, reflected mainly in the production of glazed tiles. This can mainly be attributed to the slump in the housing/construction market caused by the recession in the late 1980's to early 1990's. This forced UK tile manufacturers to seek growth in overseas markets, reflected in the rise in export values from 1990 onwards, as seen in Table 8.5.

	1987	1988	1989	1990	1991	1992	1993	1994
Exports	9.5	8.4	9.2	13.7	12.8	15.0	23.3	21.8
Imports	88.1	106.6	121.8	116.5	109.9	96.0	86.1	131.2

Table 8.5 : Comparison of Import & Exports Sales Values (£m at 1991 prices) (141)

However, Table 8.5 also shows the increased competitive pressures from overseas manufacturers as imports, particularly between 1988 and 1991, rising again in 1994. As a result of increased foreign competition the large UK tile manufacturers have had to automate plant processes and maintain a strict control over costs. On this basis the tile sector is seen to lead the way in the installation of energy efficient technologies within the ceramics sector. Figure 8.1 displays changes in UK Tile manufacturing output to 1994, showing recovery from 1993.

Figure 8.1 : Tile Sector Market Sales 1987-94. (141)

Tableware Sector Production Trends

The UK tableware industry is characterised by its very diverse nature, consisting of some 770 companies and employing 43 000 people in 1992 (141). Over the last decade there has been a trend towards rationalisation and concentration, with many of the smaller companies closing. The major companies are Royal Doulton, Wedgwood, Staffordshire Tableware, Churchill Tableware, John Tams Group, and Royal Worcester. The products are categorised as being bone china, earthenware or stoneware.

Royal Doulton accounts for more than 50% of the UK china industry, Wedgwood 25% of ceramics tableware, and Staffordshire Tableware more than 50% of the earthenware market (142). Wedgwood and Royal Doulton combined account for 36.5% of the total UK tableware market (142). In 1992 the UK retail market for china and earthenware was worth £1.07 billion, with tableware and kitchenware representing 70% of the sales and 30% from giftware (142). Table 8.6 provides market figures.

SALES £M	1986	1987	1988	1989	1990	1991	1992	1993	1994
China and Porcelain	192.6	197.6	226.8	258.8	264.3	265.4	251.1	315.0	349.2
Earthenware	191.3	200.9	211.8	231.5	235.3	216.6	223.0	268.6	268.3
Other	38.9	40.3	48.8	55.8	50.4	58.8	56.8	44.4	44.4
Price Index (1985 =100)	106.2	111.8	119.1	130.1	114.5	159.9	-	-	-

Table 8.5 : Market Sales Value for Tableware Sector (£m 1991 Prices) (142)

The growth of china, porcelain and other tableware over the period from 1986-94 has increased significantly. Earthenware, however, has remained fairly constant. Market analysts have predicted that tableware sales in china and earthenware represent a growth market. Previous forecasts have suggested market expansion from £1070 million in 1992 to £1427 million in 1996 (142). Figure 8.2 displays the trend in UK tableware market sales from 1986-94.

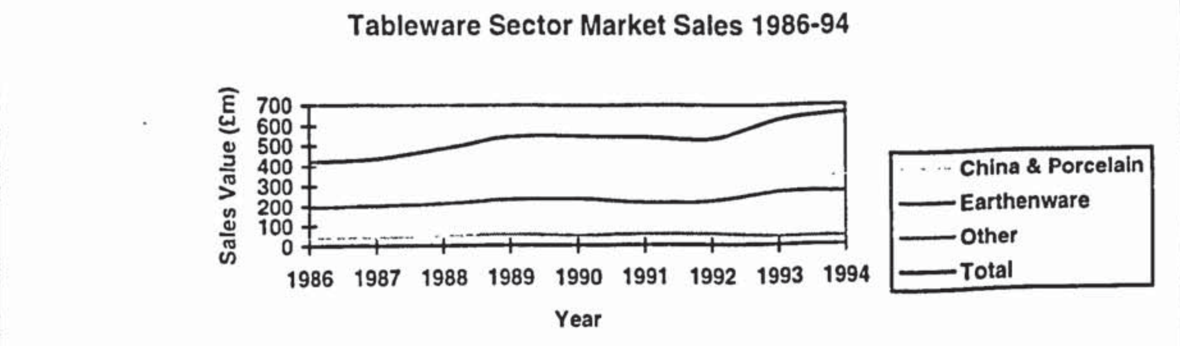

Figure 8.2 Tableware Market Sales 1986-94 (142)

The Ceramics Manufacturing Process - Sanitaryware, Tableware and Tiles

The following sections provide a brief overview of the manufacturing process within the ceramics sector. The overview is presented in an order which corresponds to the production stages involved in the manufacture of ceramic products.

Materials Preparation

The vast majority of manufacturers produce their products from slip; an aqueous suspension of clay, filler and flux, with a solids content of around 70%. Ceramics manufacturers are seen to either produce their own slip on site, through the grinding and mixing of raw materials, or have slip bought-in in cake form or in slip form. Slip is blunged to reconstitute solids, and then continuously stirred or agitated in order to maintain its consistency. There are various technologies with which to form this slip, depending upon the nature of the product in terms of size, type, and shape, but there is a high reliance upon traditional craft skills, particularly in the tableware sector. A typical process flow is shown in Figure 8.3.

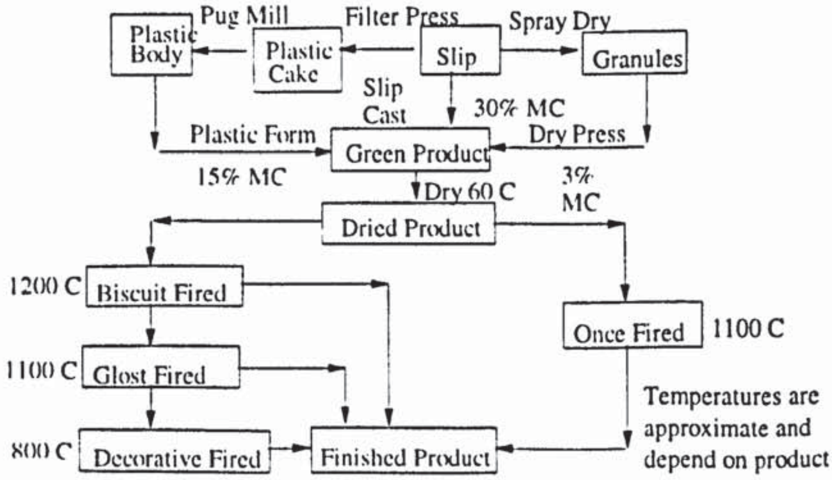

Figure 8.3 : Typical ceramic process flow (43)

Casting/Forming

This process involves the taking of the slip, plastic body, or granules and then correspondingly moulding, forming or pressing it to a solid form for use in manufacturing the end product. There are three main methods:

i. Drying of Slip to Powder Form

During this process slip is wet ground in a batch process and then spray dried to form granules which are suitable for dry pressing in a die. 'Green' products produced in this fashion have very low moisture contents, typically of between 3-6%. There are two methods of pressing, namely hydraulic and mechanical. The hydraulic method allows greater control and higher pressures than the mechanical type but the mechanical type has higher levels of productivity. The technique of slip drying is common in the tiles sector due to its suitability for small, standard, non-complex products but has also been introduced recently in the tableware sector. The tableware sector utilises a dry powder technique known as Isostatic Pressing where a membrane holds the powder prior to being uniformly pressurised by a die.

ii. Slip Pressing

During this technique the slip is pressed to displace water content and thus produces a dense plastic body which is suitable for moulding. This technique dominates the tableware sector. The dense plastic body is often pugged after being pressed in order to remove any air content. The plastic body typically has a moisture content of 15-20% at this stage.

iii. Mould Casting

This technique entails pouring the liquid slip into a plaster mould which absorbs the water content of the slip, depositing a layer of clay on the inside surface of the mould. Once the layer of clay on the inside surface of the mould has reached an acceptable thickness then the excess slip is poured off. This technique is particularly suitable for large, complex pieces and as such prevails in the sanitaryware sector. The technique is also practised in tableware for complex items such as teapots.

Drying

The green products require drying to a specific moisture content in order to ensure that they are not damaged during the firing process. The amount of moisture remaining in the green products relates to the way in which they were formed:

- Slip Cast - 20% moisture
- Plastic Formed Ware - 12-15% moisture
- Isostatic Pressing - 1.5-3% moisture.

(43)

In addition to the drying of the green products, the moulds themselves need to be dried prior to reuse. The pressed products require very little drying, reflected by their low moisture content, and as a result this stage is often incorporated into the firing process. Those products formed by other processes require a separate drying phase whose length and temperature is determined by the moisture content of the product and also its thickness. The controlled reduction of the ambient humidity is essential in order to prevent the products cracking. Drying ware in the mould presents further problems with plaster dihydrate formation limiting drying temperature. Further processes often include the drying of glazes and decoration, particularly common in the tableware sector.

Dryers are mainly of a continuous type using turntables or conveyers to move the ware through a heated chamber. However, for larger products, particularly those in the sanitaryware sector, intermittent dryers can be used. In common use is the technique of open shop drying, through which products are left on a rack and ambient temperature is raised to stimulate the drying process. Many drying techniques in use today are often cited as being inefficient, primarily due to outdated equipment. In addition to this, most manufacturers do not perceive a need to address the problem as the cost of energy has traditionally been low compared to other production costs.

Glazing

Glazing involves the application of glaze to the product surface in order to provide a quality finish upon firing. Glazing is carried out by robotics or more traditional hand-spraying. Products at the extreme quality end of the manufacturing spectrum are often hand decorated and glazed. This is particularly true of the tableware industry.

Firing

The firing process is determined by the type of product to be fired and its desired quality level. It is common for sanitaryware and cheap tableware to be once-fired, with any decoration or glaze applied prior to the firing process. Tile manufacturers use once-firing for their redware floor tiles.

For other products, including some sanitaryware, products are fired more than once. An initial firing is made to increase strength (biscuit firing), with a successive firing process after the application of decoration and glaze (glost firing). This firing schedule is typical of wall tiles and tableware sectors.

High quality tableware can sometimes be subjected to a third firing process. This is often associated with high quality decorative requirements and is known as Enamel Firing. Typical temperatures for each firing process are as follows:

1. Biscuit - 1000°C
2. Glost - 1000 to 1200°C
3. Enamel - 800°C

Kilns are of two types. The first are the continuous or 'tunnel' kilns. In this arrangement ware is moved through the kilns on kiln cars and is stacked, often several layers high, on kiln racks. Roller kilns are a modernised version of tunnel kilns and utilise silicon carbide rollers. The ware is conveyed through the kilns on the rollers, improving production rates and also fuel efficiency as the reduction of kiln furniture reduces the number of heat sinks.

Intermittent kilns have to be loaded and unloaded at each firing but do allow flexibility in production. These kilns also use large amounts of kiln furniture to support ware. However, in some designs the actual kiln is lifted over the ware in order to minimise handling.

In order to perform any study into the potential for DSM within an industrial sector it is vital that an attempt is made to assess, with a reasonable degree of accuracy, the amounts and timings of energy usage by the sector. Such an analysis will primarily focus upon usage of electricity and is applied to the sanitaryware sector in Chapter 9.

CHAPTER 9

DSM BY INDUSTRIAL SUB-SECTOR:

ANALYSIS AND ASSESSMENT OF END-USE TECHNOLOGIES AND ELECTRICITY UTILISATION AS APPLIED TO THE SANITARYWARE SECTOR

Introduction

In order to ascertain the true benefits of the sub sector approach to DSM via energy services it is necessary to focus upon a specific subsector of the ceramics industry. As such, the main thrust of Chapter 9 will concern the sanitaryware sector. A first-order energy audit on every sanitaryware manufacturing site in the UK will provide an insight into the similarities of electricity utilisation within a particular subsector. This will in turn allow an assessment to be made of the potential for developing methods which would allow a prediction of the operating times and likely electrical demands of end-use technologies within the subsector.

End uses such as pumping, compressors, and lighting will be difficult in this respect, being related to varying extents to parameters beyond purely production throughput levels. Lighting load, for example, is variable in accordance with site parameters such as level of natural light, technology type, and control method. This is covered later in the chapter.

The Sanitaryware Sector: An Overview of the Production Process

Products in the sanitaryware sector tend to be larger and more complex than those produced by other ceramics sectors. The range of products extends to kitchens, bathrooms, and lavatories.

The majority of products are made from vitreous china which is composed of 30% quartz, 25% china clay, 25% ball clay, and 20% feldspar (133) and are formed by traditional slip casting techniques. Due to the physical dimensions of the products and the relatively high moisture content associated with traditional slip casting, shop drying times of 24 hours in the mould are common. Moulds are produced from a mixture of plaster and water which is then cast in metal formers. The moulds themselves then need to be dried. This can be achieved through the use of heatpumps, conditioning chambers, and other techniques including shop drying.

The technique of shop-drying is widely practised in the sanitaryware sector. This involves the steady increase of ambient temperature in the workspace to a specified level, allowing the products to dry openly overnight. The heat sources are usually direct and indirect gas burners. Moulds are often dried in a similar fashion to the finished products, each mould lasting approximately 120 cycles before becoming ineffective (105).

Continuous drying processes are not common. Often it is gas fired intermittent chamber dryers which dominate. Products entering these chambers have moisture contents around 11-13% and are dried to less than 1% prior to firing. The actual drying temperature depends upon the product type, but ranges from 45-90°C. Drying times can reach 48 hours for some products and, in a recent survey, manufacturers regarded the drying stage as the bottleneck in the production process (43). Once the drying phase is completed products are glazed and then once fired at temperatures of around 1250°C.

Table 9.1 provides an insight into the range of electricity consumptions by process area as found in this survey, as undertaken by the author. The sector range is derived from site specific surveys carried out at all UK sanitaryware manufacturing sites.

	MWh/yr Consumed	**Electricity Cost (£k/yr)**	**Site Electricity Electricity Usage (%)**	***Sector Process-Range Energy Usage (%)***
Material Preparation	973	39	15 %	***10–20***
Casting	224	9	3 %	***1–5***
Drying	384	16	6 %	***5-20***
Glazing	37	1.5	0.5 %	***0.5-1.0***
Firing	1382	58.5	21 %	***15–25***
Ventilation	1460	59	22 %	***15-25***
Compressors	288	11.5	4 %	***3-8***
Lighting	1890	75.8	28.5 %	***15-30***
Total	6638	270.2		

Table 9.1 : Electricity Consumption in the Sanitaryware Sector by Process Area

[The site specific figures in Table 9.1 are based upon a sanitaryware manufacturer producing 10-12 thousand pieces per week, utilising chamber dryers, pressure casting on ten percent of ware, and tunnel kilns. Electricity is based upon 4.0 p/kWh at all periods.]

Figure 9.1 provides a flow diagram of the entire manufacturing process.

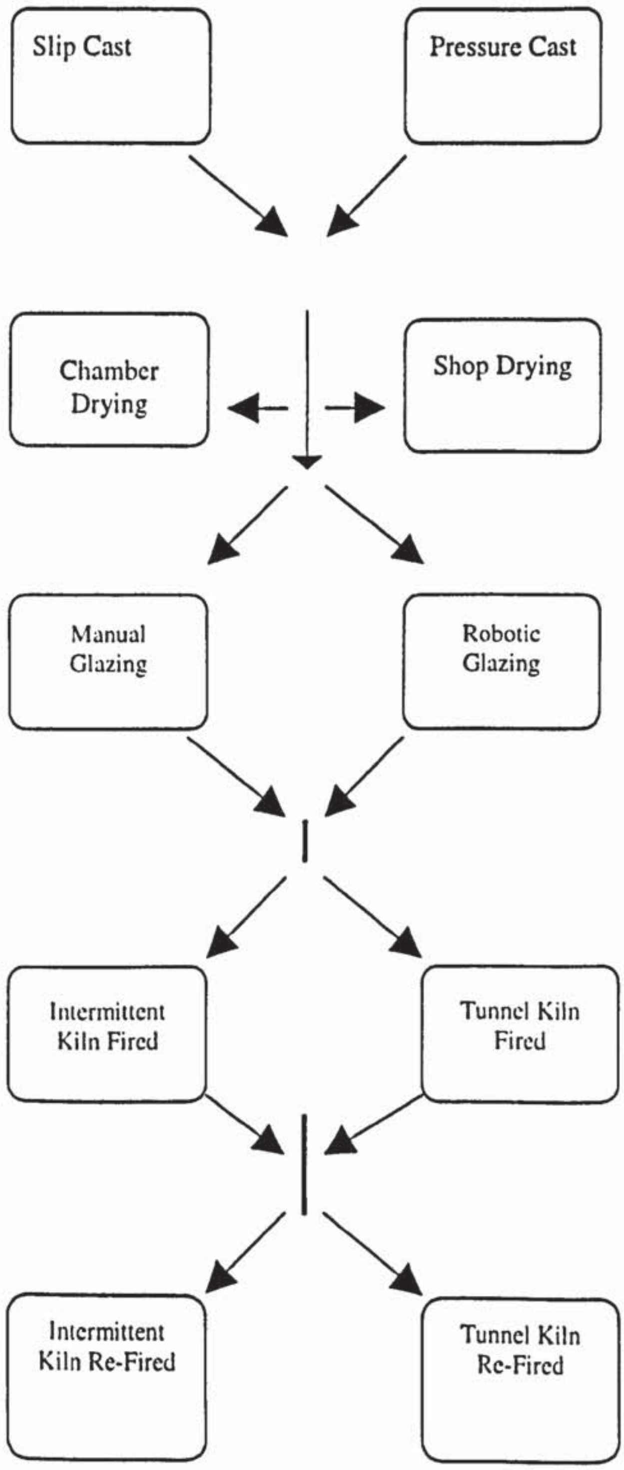

Figure 9.1 : Ceramics Manufacturing Process Flow

Each stage of the production process, as applied to the sanitaryware sector, will be analysed in the following pages. This will be done in terms of end-use technology application and applicability to DSM or Energy Service opportunities.

Process Stage: Materials Preparation

Introduction

Energy utilisation within the materials preparation process is dominated by the application of induction motors driving processes such as grinding, mixing, and pumping. As such, electricity demand and consumption within this process step is relatively high when compared with other process stages such as casting, drying, and firing. The process flow is illustrated in Figure 9.2.

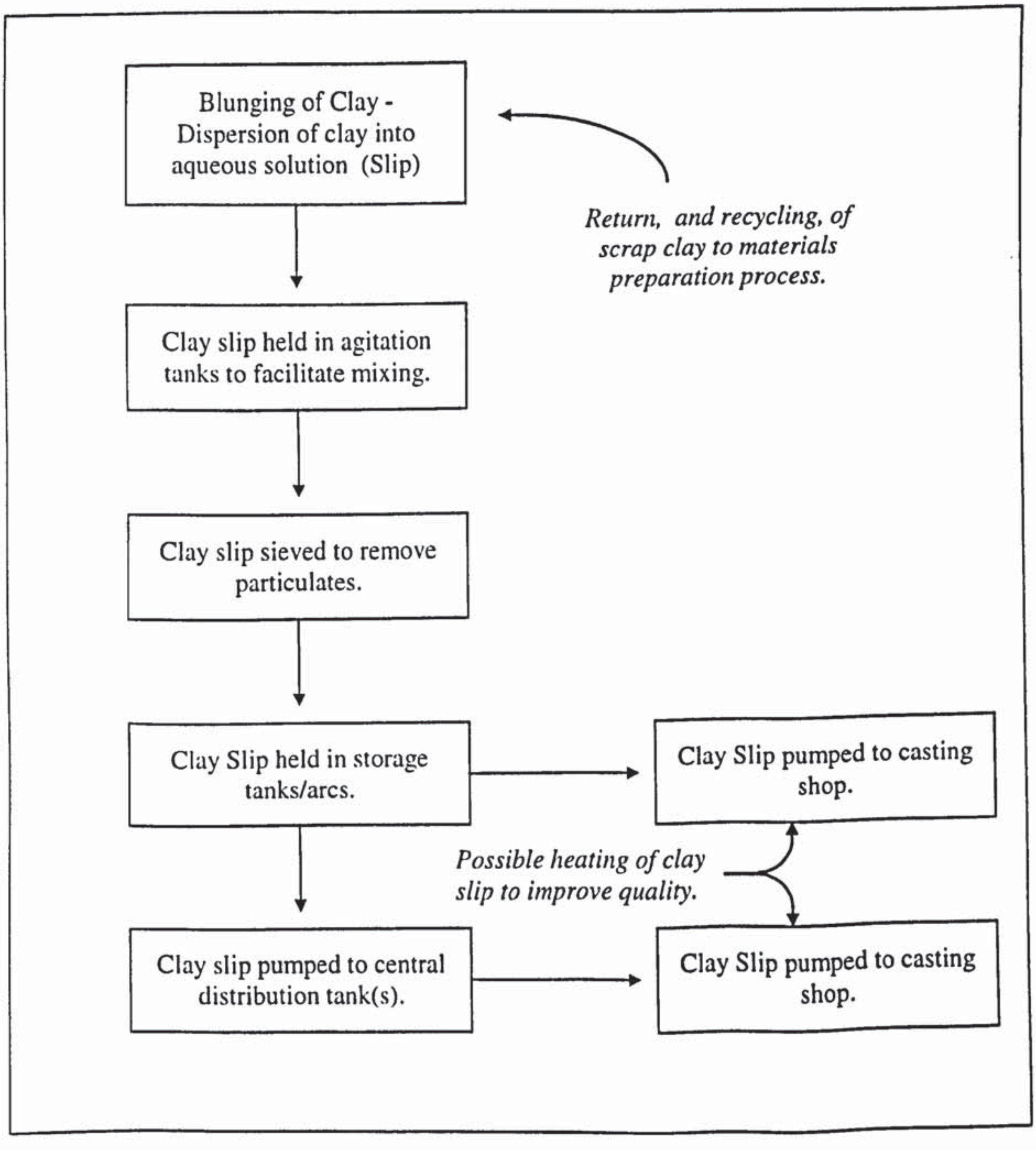

Figure 9.2 : Process Flow Diagram of Materials Preparation Process

Energy Utilisation

The electricity demand profile associated with materials preparation depicts a relatively constant base load, attributable to holding and agitation tanks which utilise constant speed motors running continuously in order to maintain slip consistency. The variable load associated with slip production is attributable to 'blunging', the term utilised to describe the reconstitution of solid clay into suspension. During this process step a weighed measure of clay is 'blunged' into the required volume of water for the creation of clay slip. It is the blunging process which drives preparation base load higher, typically starting between 03:00 and 05:00 hours on larger sites (production in excess of ten thousand pieces per week), and around 07:00 at smaller sites (production under five thousand pieces per week).

The blunging and slip storage/mixing profiles shown in Figures X&Y of Appendix A have been obtained through the real-time on-site logging of end-use devices at a particular manufacturing site producing approximately 10,000 pieces per week. The energy audits carried out as part of this thesis have shown that manufacturers use highly similar equipment, with variations attributable to motor size and number of units.

Further variation in load is attributable to pumping requirements. Pumps are utilised to transport the slip within its own production process area into tanks and arcs, and also into the process area of casting. Electrical pumping load is the most difficult to quantify accurately without monitoring and recording equipment, being related to production requirements on a product type and throughput basis, as well as the physical distance of the casting shop from the materials preparation area. However, a pumping profile has been obtained from one manufacturer. This profile is considered to be typical in terms of the timing of demand although absolute magnitude of load will vary from site to site for reasons mentioned.

Materials preparation typically accounts for between 7-22% of instantaneous electricity demand, and 10-15% of total annual consumption, on surveyed sanitaryware sites. Table 9.2 lists the major electricity utilisation within the process area of materials preparation.

Device	kW Rating	Purpose	Load	Cycle Times
Blungers	20 - 50kW	Reconstitution of solid clay into slip.	Constant speed.	Between 05:00 & 12:00. Typically each charge requires a maximum of two hours per cycle. Number of cycles per day reflects site production volume & slip storage capacity.
Agitators	4 - 7kW	Continuous mixing of slip from blunging tanks prior to sieving out of small particulates of solid clay.	Constant speed application.	Standard size. Typically run for twenty four hours to prevent settling of clay particles. Number of agitators corresponds to site size. Size of motor reflects capacity of tank.
Sieves/ Vibrators	1 - 2 kW	Screening & removal of clay particulates.	Constant speed application.	Standard size. Typically run intermittently for approximately two hours per day as required. Number of devices reflects production volume/capacity of site.
Storage Arcs	5 - 7 kW	Constant mixing to ensure consistency of slip.	Constant speed application.	Standard size. Tanks typically below floor level. Motor size varies slightly with tank capacity. Number of tanks and size relates to production volume/capacity of site. 24 hour process.
Storage Tanks	4 - 6 kW	Constant mixing to ensure consistency of slip. Holding stage prior to pumping of slip to casting shops.	Constant speed application.	Size of motor reflects storage capacity of tanks. Number of tanks reflects to production volume/capacity of site. 24 hour process

Table 9.2 : End use applications associated with materials preparation in the sanitaryware industry.

Forty percent of sanitaryware production sites utilise heating in order to raise the temperature of slip prior to pumping to the casting areas. Heat is traditionally raised through boilers via steam distribution or through gas burners. Improved cast quality is the primary reason for the heating process, due to the slip experiencing less air ingress during pumping as a result of its reduced viscosity after heating. This application area provides opportunities for Ohmic heating, an electro-technology capable of delivering significant improvements over traditional heating methods. The numbers and types of devices utilised during materials preparation, as found in this survey of sanitaryware manufactures, is shown in Table 9.3. Cumulative load refers to the total installed capacity of devices utilised for materials preparation within the UK sanitaryware sector.

Process	No. of UK Sites	No. Devices	CapacityRange of Devices (kW)	Cumulative Load (kW)
Blunging	12	33	11 - 55	1120
Scrap Blunging	12	18	11 - 55	602
Sieving	12	62	1.5 - 2	108
Agitation Tanks	7	21	5 - 7.5	322
Storage Arcs	5	42	5 - 6	160
Casting Tanks	8	36	2 - 15	155

Table 9.3 : Number and kW Ratings of Process Technologies Within Sanitaryware Sector

DSM Options in Materials Preparation

As electric motors represent the major energy consumption of the materials preparation process, DSM options relate primarily to the use of Higher Efficiency Motors (HEMs), Variable Speed Drives (VSDs), and Soft Starters.

HEM's do not offer great potential for the reduction of electrical demand, typically 2-4%, but are particularly attractive from an energy consumption viewpoint. This is most apparent when considering those motors which have high levels of utilisation, such as those used for continuous mixing of slip in storage and agitation tanks. The economics of applying HEM's to replace standard motors in other applications such as blunging and sieving need careful consideration of running hours, due to their intermittent operation. The potential for application of HEM's is considerable, with many manufacturers of sanitaryware not being aware of the recent convergence of price between HEM's and standard motors (105, 133).

Speed control on motor applications in materials preparation would appear not to have been fully considered in the sanitaryware industry. There is little evidence of exploratory work on the feasibility of applying VSD application to slip storage tanks and agitators. Conversations with plant operatives have revealed that considerable reassurance would be required with regards to slip quality in order to consider the application of speed control. If speed control were to prove to be feasible, it may be possible to minimally load a significant number of motors for a significant period of time, mainly outside production hours. The monitoring of torque/sheer on the drive shaft of the mixing paddle has been suggested as a possible means of facilitating speed control (105).

Blunging, representing the heaviest motor loading in the materials preparation process, is also an area in which speed control has had little consideration. At only one site was there an attempt to reduce motor speed, and hence kW demand and kWh consumption, over the blunging cycle. At the site where this was undertaken, demand was reduced by nearly 50% over the second half of the blunging cycle. VSD application on blunger motors would not be particularly financially attractive due to the relatively low levels of utilisation and the short cycle times (often only two to three hours) of the blunging process.

Table 9.4 represents the opportunities for various DSM load shaping objectives within the process stage of materials preparation.

DSM Technology	Application Area	Load Growth	Peak Reduction	Load Leveling	Valley Filling	Conservation	Dynamic Load Shaping
HEMs	**All motors on slip tanks, blungers, underground arcs etc.**	×	×	×	×	✓✓	×
VSDs	**Potential on slip tanks.**	×	×	×	×	✓	×
Twin Speed Motors	**Blunging, Slip tanks.**	×	✓✓	× ×	× ×	✓✓ ✓✓	× ×
Ohmic Heating	**Pre-heating of slip, particularly pressure cast.**	✓✓	×	×	×	(✓)	×

Table 9.4 : DSM Opportunities within Materials Preparation

Technology Applicable for Load Shaping Objective ✓✓; Technology Conditionally Able to Deliver Load Shaping Objective {✓}; Applicable to Gas (✓); Technology not Applicable for Load Shaping Objective ×.

Cost Appraisal

A cost appraisal of certain measures applicable to the materials preparation process of a typical sanitaryware manufacturer, producing the mean output of the UK sector range, is given in Table 9.5.

	% Total Site Consumption	% Process Consumption	Operating Cost (£k/yr)
Materials Preparation	**10.0 %**	**-**	**21**
Blunging	**1.5 %**	**15.5 %**	**1.51**
Agitation Tanks	**1.7 %**	**18.0 %**	**3.97**
Casting Tanks	**3.4 %**	**35.5 %**	**7.49**
Pumping	**2.8 %**	**30.2 %**	**5.74**

Table 9.5 : Relative Electricity Consumption by Process Stage.

[The site specific figures in Table 9.1 are based upon a sanitaryware manufacturer producing 10-12 thousand pieces per week, utilising chamber dryers, pressure casting on ten percent of ware, and tunnel kilns. Electricity is based upon 4.0 p/kWh at all periods.]

Materials preparation typically represents a low to moderate fraction (10-20 %) of the annual electricity consumption of a sanitaryware site. As such, the process has received little attention for the consideration of the installation of energy efficient devices. However, the motors contained within materials preparation contribute significantly to the overnight load, mainly by virtue of the fact that almost half of the motors run continuously. Also, it is within the process of materials preparation that the largest motors on a sanitaryware site can be found i.e. blunging. Blunging is a process which has potential for DSM technologies and load shifting. Table 9.6 shows the cost effectiveness of applicable DSM technologies on identified electric motors within the materials preparation process.

DSM Measure	Application Area	% Change in Process Demand	% Change in Consumption	Cost of Measure (£)	Value of Savings (£/yr)	Payback (years)
HEMs	Ball Clay Tanks Casting Tanks	(-) 3 - 5 %	(-) 3 - 5 %	550**	373	1.5
VSDs	Casting Tanks*	+ 30 to - 50 %	(-) 20%	6000	1498	4.0
Twin Speed Motors	Blungers	(-) 50 % for 2nd half of cycle	(-) 25 %	1000**	435	2.3

Table 9.6 : Cost Effectiveness of DSM Measures in Materials Preparation Process

** Technical feasibility unknown.*

*** Refers to additional cost above standard motor.*

The application of VSDs on slip tanks is a relatively untried concept. Slip is, at present, mixed continuously as soon as it is reconstituted to water from the blunging process. The cost analysis has taken into account the fact that electricity demand would rise above that required by constant mixing due to the implied increase in mixing speed to enable the slip to attain the required consistency in a short time period. The projected payback for the technology at an annual saving of £1498 is put at four years. Payback has been utilised as a financial assessment of proposed measures as this is the technique that most manufacturers apply when considering investment in new technologies.

Twin speed motor application is under utilised in the blunging stage of materials preparation. The application of a twin speed motor has been demonstrated as being viable at a sanitaryware site visited during this study. The motor demand is reduced by approximately fifty per cent over the second half of the process, leading to a reduction in energy consumption of twenty five percent. This DSM technology application leads to a projected payback of just over two years.

The application of HEMs to materials preparation is explicitly linked to the operating hours of the motors. As operating hours increase, so does the amount of savings. In terms of electricity demand, HEM application would have little influence, a reduction of around three percent per motor being the norm. The major application area within materials preparation is that of continuous mixing within slip storage vessels. However, HEMs do offer substantial running cost savings over their standard counterparts in terms of kWh as opposed to any kW demand reduction.

Process Area: Casting

Introduction

Sanitaryware is formed through slip casting. Slip casting is utilised in order to produce complex, hollow items. Slip is traditionally poured into a plaster mould which absorbs the moisture, causing clay to build up along the internal surfaces of the hollow mould. Moulds are filled and then left for a period of time to allow this process to occur, whereupon excess slip is poured off. Upon pour-off the piece has a typical moisture content of around twenty per cent (105). The mould is left in place until a sufficient amount of the slip's water content has been absorbed.

The alternative to manual casting via the pouring of slip into moulds is the technique of pressure casting. In this technique compressed air is utilised to pump slip at high pressure into a battery of moulds. The technique offers significant increases in throughput over the conventional manual technique but, at present, is mainly utilised for high volume, relatively simple, shapes.

The casting process typically begins at 06:00 hrs, with a standard nine hour production shift. The number of casts per day varies by factory and casting technique utilised. Many factories work on the basis of two casts per shift. The electrical loading during this period shows little variation, with constant speed motors pumping slip through a one-way valve across the entire shift period. When slip flow lines are closed the pump is running against this closed valve (see Appendix A for load profiles).

Pressure casting machines typically account for no more than ten per cent of throughput at sites where it has been adopted. These machines are maximised in terms of utilisation, with operating times of sixteen to twenty hours per day, due to their high capital cost. It has been found that pressure casting typically represents thirty percent of instantaneous maximum kW compressor demand. This figure obviously changes in response to fluctuations in compressed air demands throughout the site for a variety of applications over a full production day.

Energy Utilisation

The casting process is characterised by a relatively low energy requirement. Energy consumption which does occur for the casting process is dominated by the utilisation of induction motors. In manual casting induction motors are utilised to pump slip from the materials preparation process, to the casting benches, via 'slip-lines'. For pressure casting compressors are utilised to pump slip at high pressure into casting batteries, making this technique more energy intensive. A report on energy utilisation in the European sanitaryware sector (130) revealed an average SEC for manual casting of 0.01 GJ/t, rising to 0.1 GJ/t for pressure casting. This survey has revealed an average SEC of 0.0324 GJ/t for manual casting and 0.324 GJ/t for pressure casting.

The utilisation of electricity within the casting process has been calculated as consuming 0.5 to 3.0 per cent of total site kWh. Instantaneous demand ranges from 1.0 to 2.0 per cent of site total kW demand. The higher values of these ranges are based upon those sites utilising pressure casting.

Casting Technique	Number Of Sites	% of Sector Throughput
Bench Casting	12	35
Battery Casting	7	42.5
Beam Casting	9	20
Capillary Vacuum Casting	2	0.5
Pressure Casting	6	2

Table 9.7 : Casting Techniques within the UK Sanitaryware Industry.

As can be seen from Table 9.7, pressure casting and vacuum casting represent only 2.5% of UK sanitaryware throughput. Both techniques are considered to be at an experimental stage, with pressure casting uptake only likely to see significant increase if the drying process cycle times can be shortened or production process automation can be advanced.

The drying process, with cycle times reaching around 12 hours in most modern chamber dryers for a sanitaryware load, is often the bottleneck in the manufacturing process. Pressure casting machines are, to a pratical extent, limited in the complexity of shape which can be formed. Water closets are typically in-appropriate for pressure casting. However, water closets are typically the largest pieces produced and therefore have the longest drying cycles. Manufacturers will normally dry mixed loads of ware, with the drying cycle being dictated by the 'wettest' piece. On this basis, there is little value in 'stacking' ware produced by pressure casting on shop floors, limiting the potential uptake of pressure casting technology.

DSM Options for the Casting Process

Manual Casting

Manual casting comprises bench, battery, and beam casting techniques. Bench casting is the simplest technique, comprising the successive manual filling of moulds through a single slip line. The energy involved in this process is limited to the induction motor pumping slip from storage tanks. Such pumps are typically rated at around 3.5 kW, running against a one-way valve throughout the casting process. Battery casting refers to a technique which utilises a single slip-line connected to a bench holding between 30 and 50 moulds, and as such is a more automated form of bench casting. Beam casting is set the same way as battery casting, the difference being that the moulds are pressed together through a vice arrangement.

Energy consumption through manual casting is minimal and as such is considered to be of minimal consequence. On this basis its consideration for DSM or energy services is taken no further than consideration of HEM replacement of standard motors. Table 9.8 displays the DSM technologies applicable to the casting process. The greatest impact on casting is achievable through technology substitution, considered in the following sections.

	Application Area	Load Growth	Peak Reduction	Load Leveling	Valley Filling	Conservation	Dynamic Load Shaping
HEMs	Limited number of motors on casting slip pumps.	×	×	×	×	✓✓	×
Pressure Casting	At present utilised to cast high volume, simple pieces. Typically ten per cent of throughput.	✓✓	×	×	×	×	×
Vacuum Casting	De-watering of moulds. Saves energy in mould drying only.	✓✓	×	×	×	(✓)	×
Slip Heating	Pre-heating of slip, particularly pressure cast. Speeds casting process.	✓✓	×	×	×	(✓)	×

Table 9.8 : DSM Options for the Casting Process

Technology Applicable for Load Shaping Objective ✓✓; Technology Conditionally Able to Deliver Load Shaping Objective {✓}; Applicable to Gas (✓): Technology not Applicable for Load Shaping Objective ×.

Pressure Casting

The technique of pressure casting is able to reduce casting time considerably over that of traditional manual casting, typically achieving cycle times of one hour compared to four hours or more. This is achieved through utilising compressed air to force water through the mould. Up to thirty moulds are set in a bench and then clamped, with pressure being applied at around five atmospheres. Pressure casting is, at present, limited to relatively simple shapes such as water basins. However, recent developments have led to water closets now being cast using this technique, with robotic demoulding enhancing throughput rates (130). Additionally, high pressure casting at twenty bars is now making possible the casting of complex shapes consisting of up to five parts, giving cycle times of around ten minutes for complex water closets. The main benefits over manual casting can be considered to be:

- Elimination of drying of heavy plaster moulds associated with manual casting, reducing energy consumed.

- Lower moisture content of green-ware from pressure casting leading to shorter, less energy intensive drying.
- Eliminated or reduced contamination of return slip that occurs with manual casting.
- Reduction in the number of short-life soft plaster moulds required for manual casting.

(130)

Despite the benefits of higher throughput from pressure casting, manufacturers of sanitaryware are still restricted by the batch nature process of drying. Until a continuous, rapid drying technique becomes commercially viable it appears that pressure casting will be unable to contribute its full potential within the sector. Additionally, the cost savings associated with reduced theoretical drying times are to a great extent made irrelevant due to the practice of loading dryers irrespective of the forming technique utilised.

In terms of effect on site electrical demand, it is immediately apparent that compressor loading will increase. At one sanitaryware site it was revealed that compressor demand had increased by one third (approximately 30 kW) in order to accommodate a pressure casting system producing two hundred pieces per day. However, it is possible that the overall net effect of pressure casting may not lead to increased electricity consumption as the savings on compressed air associated with mould forming, and in addition drying will decrease. Further work needs to be carried out in this area in order to establish the exact energy trade-off which occurs during the utilisation of pressure casting techniques.

Capillary Vacuum Casting

Vacuum casting is carried out through applying a vacuum to a battery of hardened plaster moulds. A framework supports the mould and the capillary tubes, which are placed along the contour lines of the mould, facilitating the removal of moisture from the mould. As a layer of clay forms on the internal surface of the mould the excess slip is drawn off and the vacuum continuously applied. With the removal of the slip the internal cavity of the mould is pressurised, assisting the formation of the piece.

The application of the vacuum does not in itself increase the speed of the casting. Benefits are derived from the fact that the mould is not required to undergo a full drying cycle, saving energy and prolonging mould life. With regards to DSM, the utilisation of an induction motor to provide the required vacuum will produce an increase in electricity consumption. It is evident from the survey that a 40 kW motor provides sufficient vacuum for the casting of up to 500 pieces per day. Again, this increase in electricity demand and consumption may be offset by the reduced cycle time and utilisation of mould dryers.

Slip Heating

The heating of slip to approximately 50°C leads to an increased migration rate of moisture through the plaster mould. The result is a reduction in casting time by between thirty and seventy per cent, product dependent (130). As such, the prime benefit is an increased throughput rate.

The technique, by virtue of the additional energy input required to raise the temperature of the slip, leads to an increase in overall energy consumption for the process unless there is a reduction in rejection rates. As such, in order to keep energy input to a minimum it is desirable to avoid the heating of bulk slip in storage tanks. Electro-heating techniques, such as ohmic or microwave heating, offer a solution to this problem. At several sites covered in the survey slip was heated prior to pressure casting, primarily to avoid the ingress of air during pumping. This was commonly carried out through resistance heating of electrodes. However, microwave technology at 50 kW was being utilised on one site, applied to moulds for up to twenty minutes in order to facilitate increased throughput. On this basis the process of heating slip represents an area of load growth in terms of a DSM option.

Electrophoresis

This technique is at an experimental stage and represents a method through which electricity consumption will increase. The technique utilises an anode(s), shaped in the form of a ceramic product, which attracts particles of clay which form a layer across the anode surface. Electro-osmosis occurs through a similar technique but draws water through a porous medium, leading to a build up of clay on the surface of the medium.

As yet, neither technique is commercially viable.

Process Stage: The Drying Process

Introduction

Energy consumption within the drying process of sanitaryware manufacture is dominated by the burning of fossil fuels. The predominant fuel is natural gas, which through combustion provides heat to assist in the removal of moisture from the product to be dried. Figure 9.4 demonstrates the process flow through the drying stage.

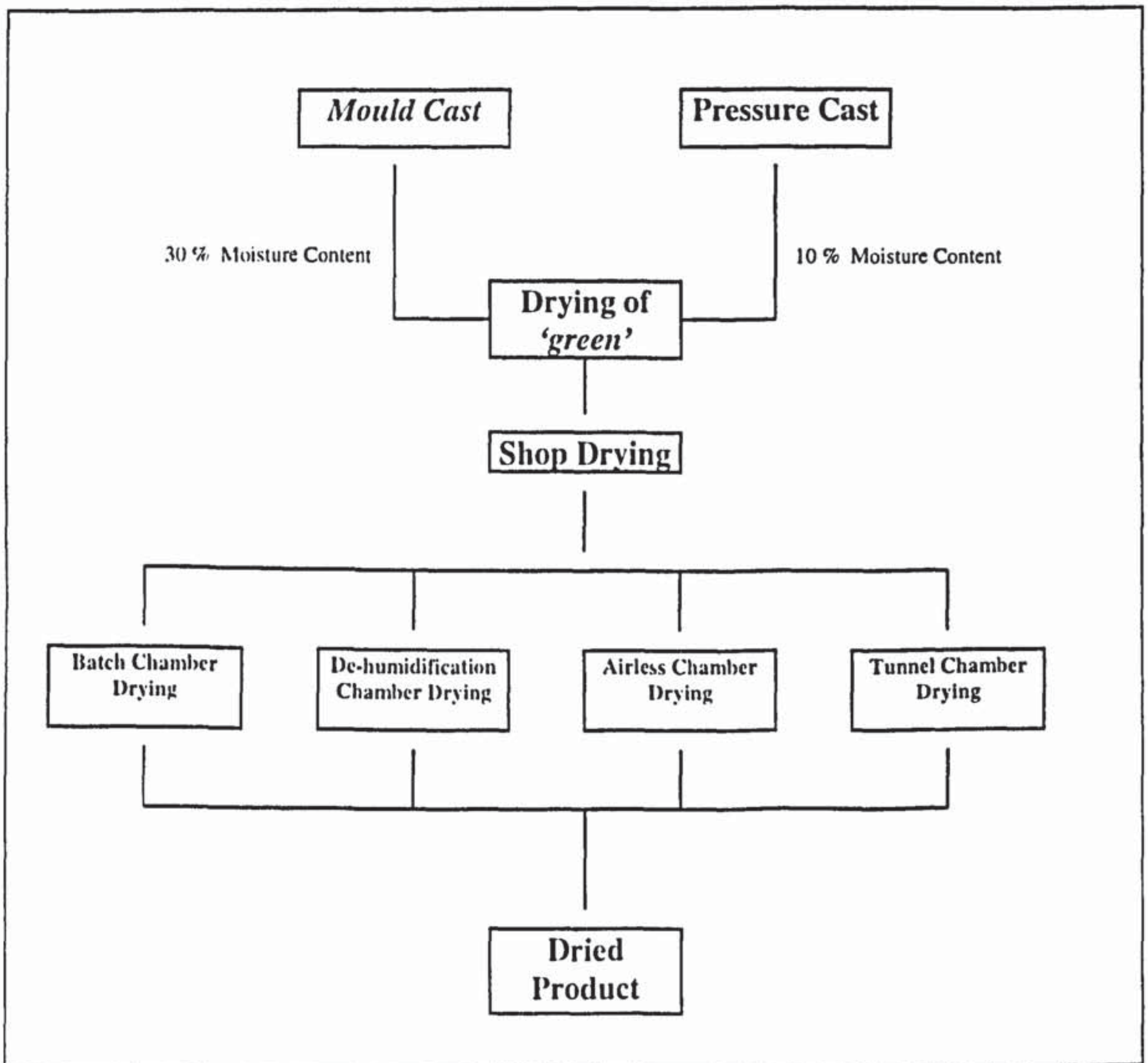

Figure 9.3 : Drying Process Flow in the Sanitaryware Industry

Prior to the firing process, moisture content of the ware is desired to be below three per cent (43). A very low moisture content is required in order to prevent the ware from distorting and cracking as it is exposed to kiln firing temperatures in excess of 1000°C. Such temperatures would cause the rapid migration of excess moisture within the ware towards the surface, creating internal stresses and resultant fractures.

The amount of moisture within a cast piece of *green* ware relates directly to the casting process under which it has been formed (*see casting section*). Slip casting in moulds is the slowest of the ceramic forming processes yet it offers the greatest flexibility for the formation of complex shapes. Generally, the pieces formed through traditional slip casting retain the highest moisture levels, up to thirty per cent (dry weight). The majority of sanitaryware pieces are formed by slip casting, although some forty percent of manufacturers now utilise pressure casting. This moisture level after casting can drop to less than 10% for the latest pressure casting techniques (130)

Sanitaryware drying is a lengthy process and presents a high load to the drying system. Relatively inefficient space heating or 'shop drying' techniques are widely practiced in the sanitaryware. A full survey of the UK sanitaryware industry revealed that every manufacturing site utilised 'shop drying' to some extent. The amount of throughput which underwent shop-drying at the sites surveyed varied from 50% to 75%.

However, shop drying was not found to be operating to the exclusion of other drying techniques at any UK site. Other drying techniques, as identified in Figure 9.4, were seen to be operating in tandem with shop drying. Table 9.9 displays the type and numbers of drying techniques being practiced by UK sanitaryware manufacturers. Two heat pump dryers were found at one site but were no longer used.

Dryer Type	% Sites Using Technique	Number of Units	Total Throughput (pieces/wk)	Average Throughput (pieces/wk/dryer)	Average Capacity per Dryer (pieces)
Chamber Dryer (direct fired)	100 %	39	62 000	1 589	317
Tunnel Dryer	15 %	3	30 000	10 000	n/a
Shop Drying Systems	100 %	17*	102 000	6 000	1 200
Heat Pump	0 %	2	0	0	400

*refers to specific site areas, related to individual casting shops

Table 9.9 : Drying Systems Employed in the UK Sanitaryware Sector.

Typical drying temperatures vary from 40 °C, for shop drying, to 90 °C for tunnel drying, with typical drying times of up to 48 hours for shop drying, and 12-14 hours for chamber and tunnel drying. It should be noted that tunnel dryers are not continuous dryers. The term 'tunnel dryer' simply means a chamber dryer with doors at either end of the chamber.

Energy Utilsiation in the Drying Operation

The drying of ceramic sanitaryware is commonly achieved through the use of a combination of shop drying and chamber/tunnel gas fired drying. In this survey of the entire UK sanitaryware sector, these were the only fully utilised and commissioned techniques for the drying process. Table 9.10 depicts the electricity utilisation areas of these techniques.

Device	kW Rating	Purpose	Load / Control	Cycle Times
Shop Drying Extract Fans	5 - 15	Extraction of warm, humid, air to facilitate effectiveness of the drying process.	Constant speed. Occasionally controlled by humidity probes for on/off state.	24 hour operation. Humidity control ineffective on many sites. Where control is present, operation will become intermittent between 07:00 and 15:00. Operation is practically continuous overnight in shop drying areas.
Shop Drying Burner Fans/ Recirculation Fans	5 - 25	Utilised in order to deliver and distribute heat within the shop drying area.	Constant speed application. Often no control.	Number and size of motors depends upon the shop burner/distribution system. Sites range form multiple 5 kW motors to a single 25 kW motor. Motors run continuously in order to maintain airflow in shop drying area. Burner operation is restricted to overnight period.
Chamber Dryer Recirculation / Burner Fans.	2 - 25	Utilised in order to deliver and distribute heat within the drying chamber.	Constant speed application.	Number and size of motors depends upon the design if the chamber dryer. Chambers range from a single low kW (2-3) burner fan and multiple recirculation fans of equally low kW rating (1.5 - 3). The alternative is a single large kW rating (15 - 25) varying with chamber volume. Motors run continuously during drying.
Steam Injection.	15-30	Utilised to increase humidity within the chamber in order to optimise the drying atmosphere.	Thermostat controlled steam storage	Steam injection is utilised most heavily during 'ramp-up'. This is at the start of the drying cycle and lasts for approximately 1.5-2 hrs. Humidity is controlled in order to prevent surface shrinkage within the product.
Humidification	unknown	Refers to the technique of injecting atomised water into the chamber dryer	Compressed air lines are utilised to force water through an atomisation nozzle.	As above

Table 9.10 : Electricity Utilisation within the sanitaryware Drying Process.

Shop Drying

Shop drying represents the most energy inefficient process within the sanitaryware manufacturing process. The technique requires that ware is left in the open, often on racks or trolleys, within the casting shop or, rarely, a dedicated drying area. Space heating is then applied, typically through gas burners, in order to raise the ambient temperature to approximately 40°C. Air circulation is controlled through the utilisation of fans, representing the highest electrical loading of the technique, and consist of burner and recirculation types. Extraction of warm, humid, air is facilitated through extraction fans. These fans are operated by humidity sensors or, in other cases, run continuously under a fixed damper load. At no site was there evidence of electronic control of fan motors utilised for air extraction, despite some having motors with suitable kW rating and utilisation times.

Due to the temperatures at which shop drying is carried out, typically around 40°C, the process is scheduled away from production hours. As such it is typical for the process to begin as the final production cast is completed. From a DSM perspective the exact timing depends upon the number of shifts being utilised, either a single or a double shift, and as such the process will start at 16:00 hours or 22:00 hours respectively. Typically those sites producing less than ten thousand pieces per week will work a single shift. The shop drying process heat is removed at approximately 04:00 hours in order to cool the casting shop temperature to approximately 21°C in time for the next casting shift to begin production.

Shop drying represents a relatively high night time kW loading on a typical sanitaryware site. Night time drying load kW demand profiles for several sanitaryware sites are shown in Figure 9.5.

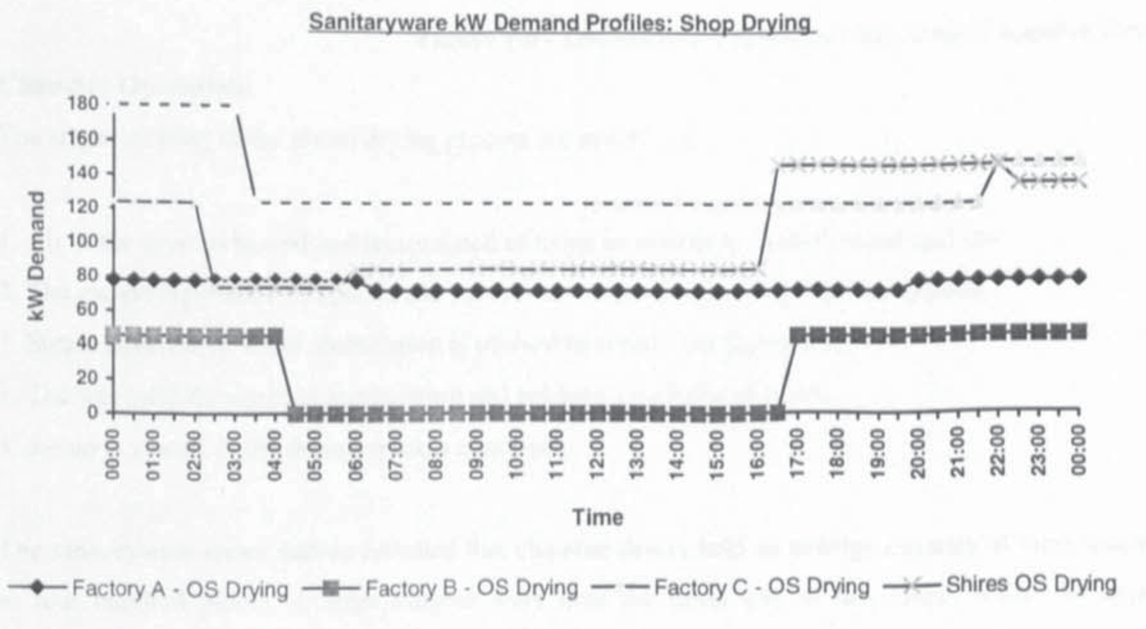

Figure 9.5 : Sanitaryware Shop Drying Profiles

The demand profiles displayed in Figure 9.5 represent the cumulative loading of induction motors for fan applications. The process of shop drying accounts for the largest fan motor ratings within a sanitaryware site. The fan applications in shop drying are typically those of burner, recirculation, and extraction. Many of these fans, particularly the extraction type, are controlled by a mechanical damper. Other fans are free-loading, running without any form of control, or are at best switched on or off through the use of a humidity probe registering moisture levels. Where heat recovery is utilised, fan loading will increase considerably. For comparative sites, a factory utilising waste heat may have a kW demand associated with the drying process up to 40% higher than a factory with the same drying throughput.

Direct Gas Fired Chamber Drying

Table 9.9 revealed that all sanitaryware manufacturing sites utilise gas fired chamber drying techniques. A diagram of a typical gas fired chamber dryer is shown in Figure 9.6.

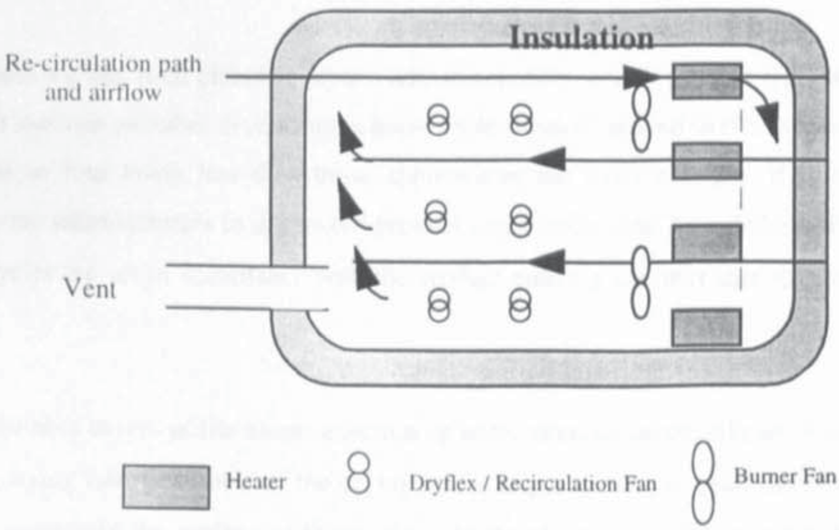

Figure 9.6 : Outline of a Typical Sanitaryware Chamber Dryer

Chamber Operation:

The stages relating to the above drying process are as follows:

1. Air in the dryer is heated and recirculated utilising an internally located heater and fan.
2. The increasingly hot air expands and part of its volume is vented through the exhaust.
3. Steam injection or water atomisation is utilised to control the drying rate.
3. The wet solid increases in temperature and releases a quantity of steam.
4. Steam is vented as the drying process continues.

The sanitaryware sector survey revealed that chamber dryers held an average capacity of three hundred to four hundred pieces. A large number were near the lower end of this range, whilst the largest chamber dryers had a capacity of approximately one thousand pieces. There were only two chamber dryers with a capacity of this magnitude within the sector.

Chamber dryers have a relatively low electrical demand, reflected in the low kW rating of many of the induction motors installed within them. The induction motors are utilised to provide airflow via fans. Fan installations on a chamber dryer are typically limited to those of burner and recirculation types. The demand rating of individual induction motors within chamber dryers is dependent upon dryer size and the desired airflow regime. In the majority of cases burner fans will have the smallest kW rated motor in the dryer, typically 1-2 kW. Recirculation fans, or dryflex fans, are typically larger at 2-4 kW. Recirculation, or air distribution, fans are found in one of two forms; dryflex or linear bank type. Dryflex's are conical in shape and attach to the ceiling of the drying chamber. Air flow through the dryflex is achieved either through an internal fan on the fixed type, or internal motor and fan on the portable type. In the linear bank arrangement, fans are fixed along both sides of the chamber and run continuously under free-load conditions.

An alternative to the multiple recirculation fans is presented through the application of a single burner fan. The single burner fan is often of a relatively large rating, 10 - 25 kW, and again runs under free-load conditions.

Cycle times for gas fired chamber dryers vary in accordance with product type and age of equipment. The most modern chamber dryers can achieve cycle times of around twelve hours for a standard water closet, up to four hours less than those approaching ten years or older. It is common practice for sanitaryware manufacturers to dry mixed product loads rather than have dedicated equipment. As such, drying cycles are set in accordance with the product entering the drier that requires the longest drying time.

All air chamber dryers utilise steam injection or water atomisation techniques in order to apply control over the drying rate. Control over the drying rate is important in the initial hours of the drying process in order to prevent the surface of the product drying too quickly. Too rapid a drying rate can cause stress fractures at the surface of the product, compromising product quality.

The steam injection units in chamber dryers are electrically powered and typically represent the largest individual kW loading of a chamber dryer, being sized from 20-30 kW. Water atomisation units utilise compressed air in order to force water through an atomisation nozzle. The utilisation of compressed air accounts for approximately forty per cent less power demand than the steam injection alternative. However, the atomisation technique could have the effect of increasing gas consumption due to the lower temperature at which water is injected into the chamber, a factor often overlooked or ignored by sanitaryware manufacturers. Figure 9.7 provides an insight into how chamber dryer electrical demand varies with chamber dryer volume.

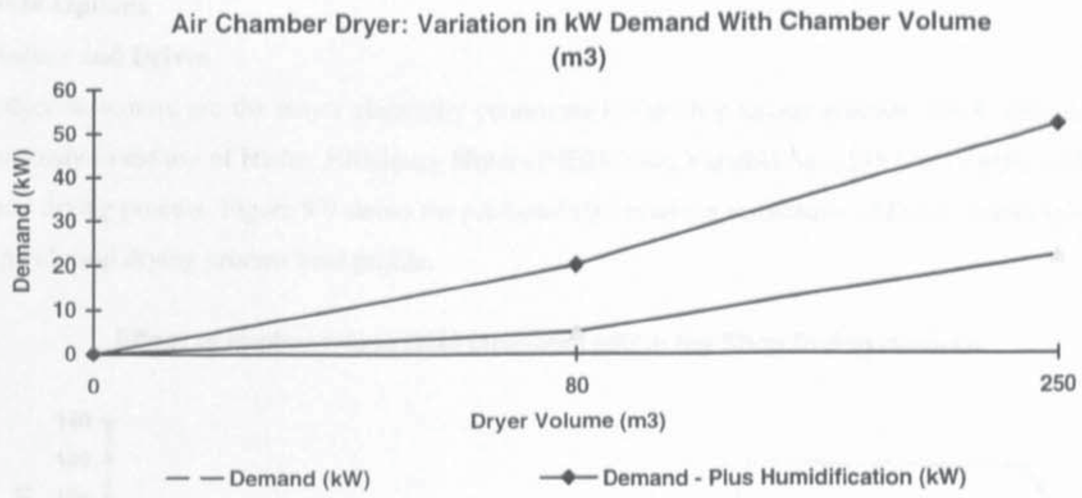

Figure 9.7 : Variation in kW demand of Chamber Dryer with Change in Dryer Volume

Figure 9.7 highlights the differences in drying cycles for sanitaryware products. The actual duration of the drying cycle is primarily a function of the age of the chamber dryer and product type. Air chamber dryers are now nearing the theoretical minimum in terms of drying cycle, as reflected by the most modern chamber dryers achieving 10-12 hour cycles. Equivalent capacity dryers of ten years or more are utilising cycles up to 25 per cent longer, at 14-16 hours. This would appear to confirm the need to maintain seals around dryer doors and minimise heat loss. The duration of the drying cycle also depends upon the physical dimensions of the product to be dried. A dedicated load of cistern lids, for example, can dry in well under ten hours. However, as stated previously, mixed loads are the norm within the sector, pushing standard drying times towards that of the product which takes longest to dry.

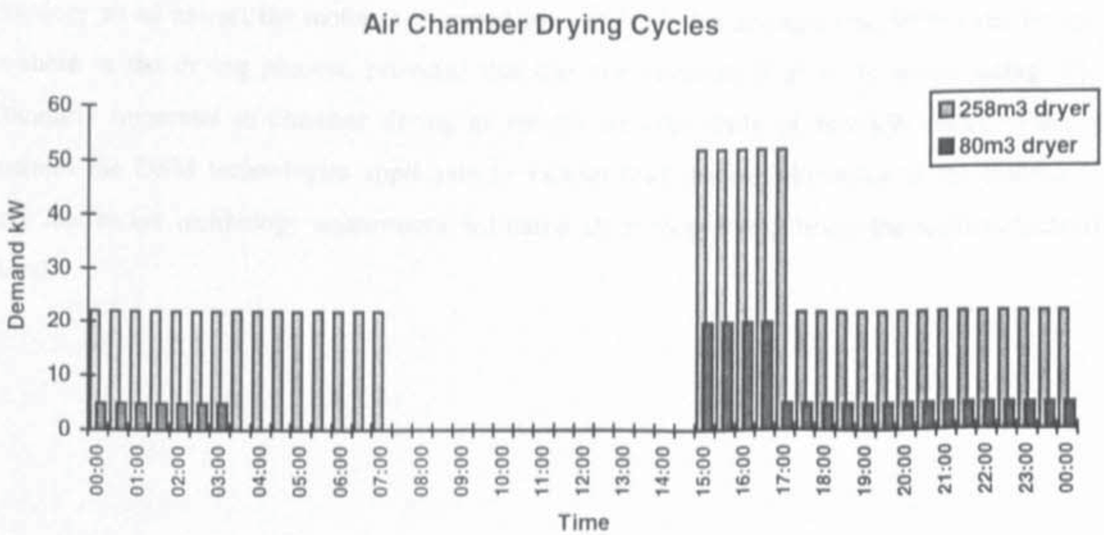

Figure 9.8 : Drying Cycle Durations for Various Sized Drying Chambers

DSM Options

Motors and Drives

Induction motors are the major electricity consumers in the shop drying process. DSM options relate primarily to the use of Higher Efficiency Motors (HEMs) and Variable Speed Drives (VSDs) within the shop drying process. Figure 9.9 shows the predicted effects of the installation of DSM technologies on a typical shop drying process load profile.

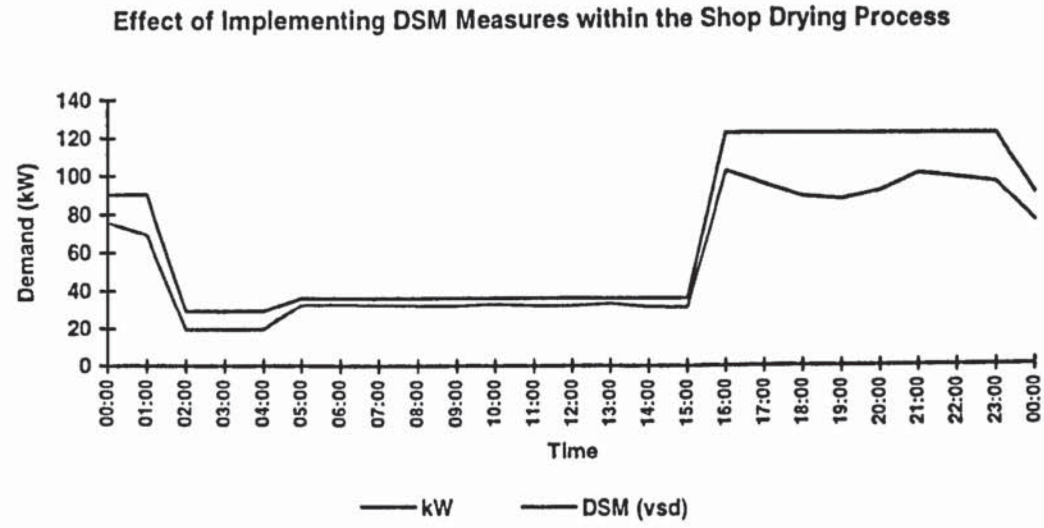

Figure 9.9 : Changes in Demand Profile Related as a Result of DSM Measures

The profile shown in Figure 9.9 is derived from substituting standard motor profiles associated with the drying process with HEM's. The effect of VSD application has been derived from applying the technology to an extract fan motor, aggregated from multiple fan arrangement. HEMs can be applied elsewhere in the drying process, provided that due consideration is given to motor sizing. This is particularly important in chamber drying as motors are commonly of low kW rating. Table 9.10 illustrates the DSM technologies applicable to various load shaping objectives at the process level. These alternative technology assessments are based upon shop-drying being the resident technology utilised.

DSM Technology	Application Area	Load Growth	Peak Reduction	Load Leveling	Valley Filling	Conservation	Dynamic Load Shaping
HEMs	All motors on shop drying systems. Suitable for larger fans in chamber dryers.	×	×	×	×	✓✓	×
VSDs	Potential on shop drying systems, particularly extract fans.	×	{✓}	×	×	✓✓	×
Heat pump dehumidification	Chamber drying utilising heat pumps	✓✓	×	×	×	(✓)	×
Heat Recovery	Recovery of heat from kilns to assist in shop drying	✓✓	×	×	×	(✓)	×
Dual Fuel Drying	Alternative drying technique, utilising RF and MW.	✓✓	{✓}	×	×	(✓)	×
Airless Drying	Alternative drying technique	✓✓	{✓}	×	×	(✓)	×

Table 9.10 : DSM Opportunities in the Sanitaryware Drying Process

Technology Applicable for Load Shaping Objective ✓✓; Technology Conditionally Able to Deliver Load Shaping Objective {✓}; Applicable to Gas (✓); Technology not Applicable for Load Shaping Objective ×.

New technology substitution in the drying process can significantly alter energy consumption levels and patterns. Figure 9.10 displays the changes in the drying process electrical load when substituting shop drying for chamber drying for an equal volume of throughput. There is a noticeable reduction in demand during the off-peak period, coupled with load growth during the on-peak period. The chamber drying profile is shown with and without steam injection in order to reflect the practice of unit disconnection which occurs on some sites.

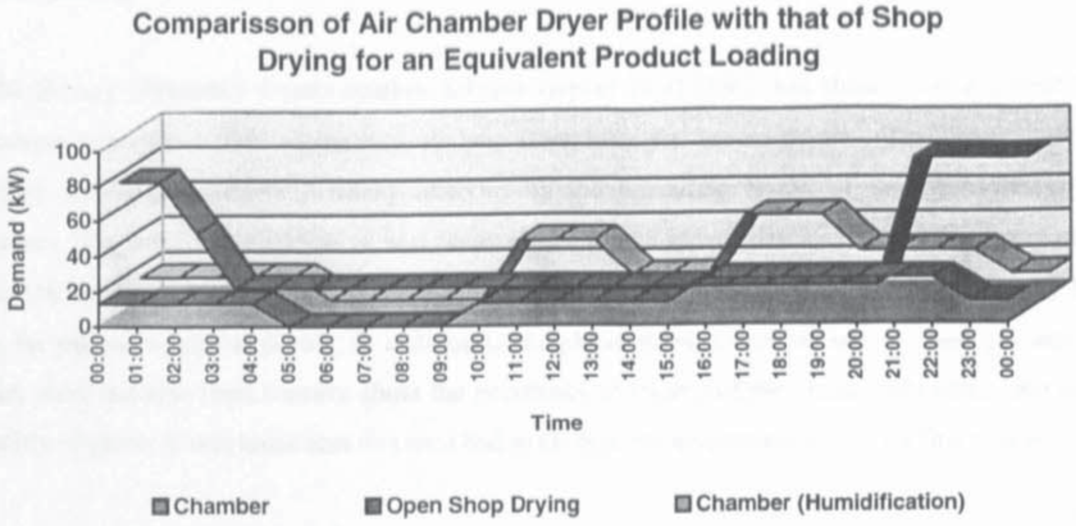

Figure9.10 : Comparison of Electrical Demands for Different Drying Techniques

The exact timing of electrical load will relate to the production scheduling at a particular site. A process manager will not operate a chamber dryer until the chamber is full to capacity. This is done in order to provide the correct airflow around the products to be dried. As such, chamber dryer systems offer a degree of flexibility in terms of the exact operating times. However, the benefits of this need to be placed in the context of the minimal kW loading associated with the chamber drying.

A notable fact observed whilst carrying out the site audits was that between 50 and 70 per cent of throughput was dried twice. The initial drying occurs within the shop floor as temperatures are raised overnight. Following this, the ware is loaded into chamber dryers and processed through a twelve hour cycle. This is a costly and wasteful process.

A lack of drying capacity in chamber dryers, and a lack of capital to rectify this, leads manufacturers to utilise shop drying to dry low complexity, smaller ware through shop drying. Often, a lack of storage space exacerbates the problem, with the drying process becoming a bottleneck in production. However, little work has been done to study the necessity of shop heating to the extremes utilised at present, as well as refinements to the production schedule itself.

On the basis of the above, further work to overcome this anomaly may prove particularly fruitful at an energy services level.

Heat Recovery

A UK Energy Efficiency Demonstration Scheme (report ED/112/97) has shown that a central heat exchanger can utilise 60% of the exhaust heat from kilns for use in dryers . The process of heat recovery has been inhibited in many factories by the prevailing layout of factory buildings and processes. The level of utilisation of heat recovery within the industry is very low. This survey of the entire UK sanitaryware industry revealed that only 15% of manufacturing sites used heat recovery from kilns for purposes such as drying. In addition to the physical restrictions of site size and process area layout, there has also been concern about the possibility of fouling of the exchanger's plates due to the volatility of glaze. It was noted that two sites had made heat exchangers redundant for this reason.

An assessment of the energy savings attributable to heat recovery would vary considerably in accordance with the site in question. Factors to be considered include type of equipment in use, plant layout, and shift patterns. However, electrical load is likely to increase due to the requirement for additional induction motors driving fans to transfer heat from source to target area. If the recovered heat is to be used for drying then this increased electrical load will be confined to the off-peak hours, typically between 22:00 hours and 04:00 hours on sites producing in excess of 10,000 pieces per week and between 16:00 and 04:00 for those producing below 10,000 pieces.

DSM: Electro-Technology Substitution

The electro-technologies applicable for the process stage in the ceramics industry are:

- Infra-red
- Radio frequency
- Microwave
- Heatpump dehumidification

Each of these technologies is considered as a possible substitute technology for the most commonly practiced open-shop drying technique.

- **Infra-Red (IR).**

Electric IR units have shown little ability to penetrate the shop-drying market in recent years, being unable to oust the dominant gas units. This is despite the fact that electric units have the benefits of a quicker response time and none of the gaseous emissions associated with gas combustion.

IR also has limited potential for application in chamber or tunnel drying techniques within the sanitaryware sector, primarily due to product quality concerns and technical difficulties. Sanitaryware pieces are complex in shape and often have a double-skin, increasing thickness. IR acts upon the surface of the body being heated, relying upon conduction to heat the inner areas. As such, heat can be attenuated at the surface and create stresses within the product. Within the UK there are no sanitaryware manufacturers utilising IR. IR has been demonstrated in the sanitaryware sector by an Italian manufacturer, who has managed to reduce drying time from twenty four hours to only two hours (130). The fact that IR has not been employed within the UK raises further questions with regards to the suitability of IR drying for the complex shapes of most sanitaryware products.

IR drying, in respect to the effects upon process electricity demand, would imply a large increase in electrical loading. The technology would greatly increase electrical load, in comparison to other predominantly gas fired technologies, for the full length of the drying process. Additional electrical loading may be required through the application of a vacuum to remove water from the product surface during IR application (130). This is in response to the attenuation of IR heating at the surface of the product due to water being a good absorber of IR wavelength.

- **Radio Frequency/Microwave Drying**

Dielectric heating is a generic term for heating an object with an alternating electric field of high frequency (between 1 MHz and 2.45 GHz). Frequencies below 300 MHz are referred to as radio frequency, and those above 300 MHz as microwaves.

Heat is delivered directly to the sub-surface volume of the solid, thereby removing the need to heat a stream of drying air. However it is now considered that, mainly due to the physical nature of sanitaryware, microwave heating would be best utilised in conjunction with more traditional drying techniques. As such the term 'dual fuel' drying is now used to describe a process stage where microwaves are applied to the product at the start of the drying process. This is done in order to quickly raise the core temperature of the product to surface temperature and therefore shorten the drying cycle. The raising of the core temperature sets up a positive pressure gradient in the product, enabling the water to be 'pumped' to the surface (125), facilitating rapid migration of water from the product.

Figure 9.11 simulates the electrical demand of a dual fuel drying process. The profile portrays an element of load growth at the start of the process in comparison to traditional gas fired drying techniques. However, the shorter drying cycle implies conservation and scope for load shifting. Cost savings are primarily delivered through shorter drying cycles and hence lower gas consumption.

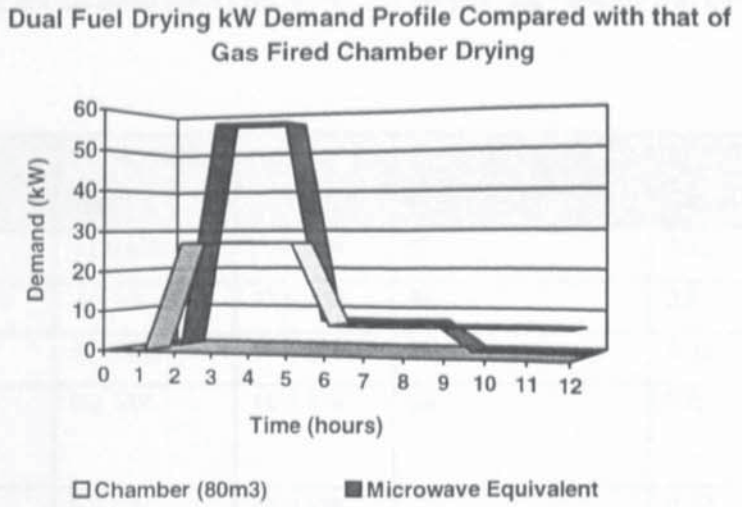

Figure 9.11 : Drying Profile of Dual Fuel Drying (derived from ref:125)

At present microwave drying is still in research stages and is not commercially available.

Heat Pump Dehumidification

In a dehumidification system the air used to dry the product is not vented off as it is in traditional 'open' systems. The moist air is instead passed through a heat exchanger where it is cooled to below its dew point. The water that is condensed from the air is then drained. The 'dry' air is then recirculated within the chamber, heated by the latent heat of condensation given up by the water.

The survey of sanitaryware manufacturers undertaken in this study revealed that heat pump drying is not in use within the sector. This is primarily due to the high running costs associated with electricity utilisation and that drying cycles are not appreciably shorter than those achievable with the latest chamber dryers (165). The installation of heat pump dehumidification would have the effect of increasing electrical load throughout the duration of the drying cycle.

Cost Appraisals

Table 9.12 provides an analysis of the operating costs of a shop drying process on a medium sized sanitaryware site producing ten thousand pieces per week. The shop drying capacity was quoted at two thousand pieces.

Application	No. motors	Motor Rating (kW)	Cumulative Load	Cum. Consumption MWh/yr	Annual Operating Cost (£k)
Inlet Fan	2	11.0 kW	22.0 kW	87	5.12
Extract Fan	4	3.0 kW	12.0 kW	96	2.8
Burner Fan	1	11.5 kW	11.5 kW	31	1.21
Underbench fans	48	0.4 kW	19.2 kW	54	2.07
Over head fans	250	0.1 kW	25.0 kW	25	0.77
Dryflex	10	5.0 kW	50.0 kW	169	5.74
Total	**315**	-	**134.7**	**462**	**17.71**

Table 9.12 : Electricity Consumption and Cost Within the Shop Drying Process

Table 9.12 shows the shop drying process to have an annual associated electricity cost in excess of £17,000 per annum. This relates to a shop drying capacity of 2000 pieces per day. The gas consumption to provide heat for the drying of 800 of these pieces costs in excess of £55,000 per year, based upon an estimated consumption of 5555 MWh per annum.

DSM Measure	Change to Process Time	Energy Consumption per Cycle	No. Cycles/dy	Energy Cost / dy
Airless Drying	Single Cast - 5hr Cycle	100 kWh/cyl (20kW) (elec.) 11,848 ft^3/cyl. (gas.)	400 pces @ 2/dy	£71.31/dy gas. £9.00/dy elec.
Gas Fired Chamber Drying	Single Cast - 12 hr cycle	160 kWh/cyl (20kW) elec. 13082 ft^3/cyl. (gas)	400 pces @ 2/dy	£77.77/dy gas £12.50/dy elec
Gas Fired Chamber Drying + Steam Injection	Single Cast - 12 hr cycle	360 kWh/cyl (20kW) elec. 13082 ft^3/cyl. (gas)	400 pces @ 2/dy	£77.77/dy gas £34.10/dy elec
Shop Drying	Single Cast - 18 hr cycle	26340 kWh/cyl (gas) 723 kWh (elec)	800 pces	£236/dy gas £32.50 elec

Table 9.13 : DSM Measure Cost Effectiveness for Drying Process
Based upon 4.5p/kWh electricity & 1.0p/kWh gas

Table 9.13 shows the relative energy cost savings through utilising airless drying as a substitute for gas-fired chamber dryers, with and without steam injection, and for shop drying. The analysis highlights the cost effective nature of new technology substitution. The application of improvements to the drying system are seen to be made cost effective primarily due to the gas savings. Influence on electricity demand is greatest when considering modifications or replacement of shop drying systems due to the relatively high motor load related to fan applications. The options presented in Table 9.13 relate to an equivalent shop drying system which consumes approximately 26,340 kWh of gas energy per drying cycle, drying 800 pieces, at a cost of £236.34 based upon 1.0 p/kWh gas. Electricity consumption for the system is 723 kWh at a cost of £32.50 per cycle. All techniques offer substantial gas-cost savings on shop drying of an equivalent throughput. The cost savings of airless drying over gas-fired chamber drying are, however, less dramatic.

Technology substitution on the grounds of energy cost reduction, even when including gas savings, becomes almost impossible in this case. On this basis, any changes from directly fired gas chamber or tunnel dryers to innovative techniques such as airless and microwave drying must be done on the grounds of increased productivity and/or quality as well as on energy cost reduction per se.

However the shifting of electricity demand when, for example, substituting shop-drying with gas-fired chamber drying, is considerable. Therefore on the basis of DSM, as opposed to straightforward energy services, the drying process could offer possibilities for areas of network facing reinforcement associated with a high off-peak load.

Process Stage: Firing

Introduction

The firing process represents the most energy intensive stage of the sanitaryware manufacturing process. Open-flame tunnel kilns dominate the sanitaryware industry, with products being once-fired. Product imperfections caused during once-firing are rectified through the use of intermittent kilns, although larger manufacturers (typically in excess of 10,000 pces/wk) utilise tunnel kilns for re-firing.

Natural gas is the prime fuel used to fire the kilns, being relatively cheap and clean-burning which makes open-flame firing possible. As such, electricity usage in kilns within the sanitaryware sector is primarily related to that utilised by motors driving circulation, extract, and inlet fans. Kilns can account for between 18% and 33% of instantaneous electricity demand on a sanitaryware site, all of which is related to induction motors driving fan applications. The percentage is primarily dependent upon the variety of other end-use technologies utilised.

Firing Techniques

A key requirement for the firing of any sanitaryware product is that the firing profile is accurately specified and controlled, and for temperature variation through each piece to be as small as possible. The reasons for this relate to the fact that sanitaryware products are typically much larger than the products manufactured by other ceramic industries. Also, most sanitaryware is once-fired, requiring the simultaneous development of both body and glaze. As such, if temperature gradients are large across the profile then the resultant stresses raised in the product can rapidly lead to distortion or cracking in the product. Additionally, imperfections in the glazed surface are readily apparent when considering that most sanitaryware is produced as part of a matching suite.

It is recognised that quality problems of cracking, dunting, spangling, and distortion are the restricting factors to kiln throughput rate for sanitaryware products (131). These problems reinforce the need to maintain the most appropriate temperature profile when firing sanitaryware.

Kiln atmosphere control is also a vital factor of sanitaryware firing when attempting to maintain glaze quality. Optimised oxygen control can produce a significant enhancement of quality levels within the firing process (131). Oxygen trimming of kiln atmospheres, done due to the tendency for manufacturers to over-compensate for the possibility of glaze fouling, can contribute significantly to obtaining an optimum SEC (131).

Other factors contributing towards obtaining a nearer optimum SEC include reducing the mass of kiln furniture. Sanitaryware is relatively light in comparison to the volume of space it occupies. The kiln furniture it rides upon is often considerably heavier and can prove to be a considerable heat sink, making accurate temperature profiles more difficult to achieve. A firing schedule for a typical sanitaryware kiln is provided in Table 9.14.

Approximate Temperature Range (^0C)	Firing Process & Conditions Required
20 - 150	Free water evaporates: air movement & ventilation are required. Water must be at least distributed evenly through the piece if not completely dry.
150 - 500	Ware can be heated quickly if dry
500 - 700	Water vapour moves to the surface of the product. Heating can be rapid due to the permeability of the body. Quartz expands suddenly at 573^{0}C. Unfired body accommodates expansion easily, however re-fired ware must be taken through this temperature slowly and uniformly.
700 - 900	Main carbon burn-out period. Ware is still permeable & thin enough to allow a fairly high heating rate.
900 - 1110	Heating of ware must be uniform prior to contraction stage. Slow contraction begins around 900^{0}C. Sulphates decompose & gases must be evolved from the body before glaze-body interface seals. Any rapid heating can cause eruptions of dried soluble salts present in local areas.
1100 - 1130	Glaze-body interface seals.
1130 - 1200	Evolved gases must now escape slowly, preferably through unglazed areas. Body continues to contract.
1200 - 1175	Very slow cooling to allow bubbles to clear from glaze without new ones generating.
1175 - 700	Rapid cooling can take place. Initially ware is pyroplastic and, even when it becomes solid, there are no rapid volume changes.
700 - 500	Cooling slowed to ensure temperature uniformity across the ware and through the setting. Cooling needs to be slow and uniform to accommodate sudden quartz contraction at 573^{0}C
500 - 300	Ware can be cooled quickly.
300	Ware can be exposed to ambient air convection provided it contains no cristobalite.

Table 9.14 : Firing Schedule for the Sanitaryware Industry. (131).

Imperfections in once-fired sanitaryware can often be remedied through grinding or retouching with glaze and then re-firing. Obviously the aim is to maximise output quality from kilns, but re-fired ware should be fired separately from first-fire ware because:

- Refire glazes can have lower maturing temperatures than once-fire. Thus, these lower temperatures lead to reduced energy consumption and less strain on the ware as it is re-fired.
- Kiln profiles can be optimised for each type of firing. Refire schedules are often longer than once-fire due to the possibility of dunting on both heating and cooling cycles.

Despite the advantages of the above approach, up to twenty per cent of UK manufacturers still combine first fire and re-fire ware in a single kiln.

Table 9.15 displays the types and numbers of kiln that are operating in the UK sanitaryware sector.

	1st Fire	Refire	Total
Intermittent - Electric	3	0	3
Intermittent - Gas	10	5	15
Tunnel - Electric	0	0	0
Tunnel - Muffle Gas	2	2	4
Tunnel - Direct Gas	15	3	18
Total	30	10	40

Table 9.15 : Kilns in the UK Sanitaryware Industry.

The vast majority of kilns are gas fired. First-fire kilns are seen to exist as both intermittent and tunnel types. Refire kilns are typically intermittent type. However, some manufacturers have utilised tunnel kilns to fire both first-fire and refire ware. Gas is the dominant fuel in both intermittent and tunnel kilns. The only electrically fired kilns within the sector were of intermittent type, with superior product quality being traded against higher fuel cost.

It has been found that the type of kiln in operation at sanitaryware sites is primarily a function of factory throughput and the physical size of the factory site.

Energy Utilisation in the Firing Process

Intermittent Kilns.

Intermittent kilns generally have fewer fans than tunnel kilns, being restricted to inlet (sometimes referred to as burner) and recirculation types. These fans are often controlled by manually adjustable dampers for the purpose of controlling kiln operating environment. Electricity consumption can account for up to 10% overall energy consumption for intermittent kilns. Table 9.16 reveals the types and ratings of fans within intermittent kilns in the sanitaryware sector.

	Present in all Kilns	kW Range	Purpose
Burner/Inlet Fan	Yes	15-45 kW	Clean air for gas burner.
Recirculation Fan	No - only muffle type	15-20 kW	Promote heat distribution in muffle kiln.
Extract Fan	No - Some rely upon exhaust or forced draught.	5-10 kW	Maintain kiln temperature profile
Exhaust Fan	No - Some are forced draught extract	15-35 kW	Forced extraction of warm, contaminated, air from kiln environment.

Table 9.16 : Electricity Utilisation within Intermittent Kiln Process

i. First-Fire:

Intermittent kilns are fired on a cyclical basis, being of moveable or fixed hearth types. Intermittent first-fire kilns are seen to prevail in the smaller, lower production level, manufacturing sites, that are typically producing less than six thousand pieces per week. These manufacturers account for seventy five percent of the utilisation of intermittent gas-fired kilns for a first-fire process. Reasons for this are:

- **Flexibility** - Intermittent kilns typically have a firing cycle of eighteen hours, giving a 'cold-to-cold' cycle time of twenty four hours. The flexibility of these kilns allows manufacturers to adjust the firing cycle quickly in order to match product type.

- **Capital Cost** - Intermittent kilns are of a lower capital cost than tunnel kilns.

- **Space** - Tunnel kilns require a large amount of factory floor space. Smaller manufacturers typically find themselves severely restricted by a lack of floor space.

Intermittent kilns typically have higher SEC values than tunnel kilns. A survey of 60% the UK sanitaryware sector by Ceram Research in 1997 (104) revealed that first-fire intermittent kilns had an average SEC of 21.3 GJ/t, sixty per cent higher than that for tunnel kilns at 14.0 GJ/t. This study has arrived at a value of nearer 11.0 GJ/t for modern intermittent first-fire kilns under ten years old, with five per cent (0.51 GJ/t) of this value being attributable to electricity consumption (figures on fuel consumptions and throughput levels were obtained from several manufacturers). Intermittent first-fire kilns over ten years old have been identified as having a typical SEC value of approximately 16.0 GJ/t, with electricity consumption being approximately 1.0 GJ/t due to the increased number of fans.

The relatively high SEC value for intermittent first-fire kilns, over tunnel first fire, highlights the trade-off between lower capital cost and flexibility of production with higher running costs in terms of fuel usage. The figures highlight the importance of maximising kiln throughput, and minimising firing cycle length, in order to improve kiln SEC.

ii. Re-fire:

Intermittent re-fire kilns are utilised across the sanitaryware sector site output ranges. These kilns are found more often on larger sites, unlike the first-fire equivalents, due to the smaller proportion of total throughput represented by re-fire ware. In this study of UK maufacturers SEC values for intermittent re-fire kilns have been estimated to be, on average, 24.0 GJ/t, compared to 19.3 GJ/t for tunnel kilns processing re-fired ware.

Sanitaryware manufacturers primarily choose intermittent kilns for re-fire for the same reasons as described for first-fire kilns, as highlighted above.

Tunnel Kilns

First Fire

Conventional tunnel kilns are effectively counter-flow heat exchangers. Ware moves through the entrance of the kiln whilst cooler air is pulled in from the exit. The effect is to draw pre-heated air over the ware as it enters the tunnel, producing a gentle warm-up period, whilst providing cooling air for ware leaving at the tunnel exit and also to pressurise the kiln. The kiln is pressurised to minimise the infiltration of cool air. Warmed inlet air flows into the kiln as secondary combustion air in open-flame kilns, or into the combustion chamber of muffle kilns.

An exhaust fan is located at the ware entrance. This pre-heat zone is characterised by the presence of excess air to ensure that burners create enough turbulence to provide a more uniform distribution of heat, reducing stratification. This oxidising atmosphere also ensures that organic compounds are oxidised. It is these exhaust fans that can be targeted for variable speed operation, optimising the oxygen level to increase kiln SEC.

Previous estimations of energy consumption or SEC values for tunnel kilns vary considerably in accordance with the report which is consulted. Tunnel kilns within the sector have been estimated as having typical SECs of between 4.0 and 8.0 GJ/t (130), or 6.0 to 22.0 GJ/t (104).This survey has found that tunnel kilns within the UK sanitaryware sector have SEC values closer to those quoted in the latter range. Seventy per cent of tunnel kilns had SEC values within the range 12-16 GJ/t with 0.8-1.0 GJ/t being electricity. As a percentage of the overall energy consumption electricity represents between 6.5-15 per cent.

There are also claims that approximately four percent of the SEC value is attributable to electricity consumption (130). However, this research has shown that a value of between ten and seventeen per cent of SEC for a tunnel kiln is nearer the true value for the UK sanitaryware. This range relates to the differences in gas consumption of tunnel kilns. For example muffle kilns are typically higher consumers of gas than direct-gas fired tunnel kilns, impacting upon the relative percentage of electricity consumption. However, direct gas-fired tunnel kilns have an average electrical SEC of 0.7 GJ/t, muffle kilns having an average electrical SEC of 0.35 GJ/t. This is primarily due to muffle kilns being of an antiquated design, relying upon forced convection/draught to maintain kiln temperature and pressure.

Tunnel kilns typically run continuously for twenty four hours per day throughout the year, primarily to maintain kiln operating temperature. As a result of this twenty-four-hour operation electricity usage is constant. This electricity usage within tunnel kilns is characterised by numerous fan loads. Burner fans, extract fans, recuperation fans, air-jet fans, and cooling fans are an example of the range of fans present within tunnel kilns. However, earlier kilns relied upon forced draught provided by chimneys to exhaust waste air.

During the commissioning stage of a tunnel kiln, fan dampers are adjusted to produce the firing profile suitable for the product range to be fired. Once set, these dampers often remain in a fixed position.

Device	Purpose	kW Range
Exhaust Fans	Remove fouled air and pre-heat incoming ware.	7 - 15
Burner Fans	Provide appropriate air levels for burner operation.	7.5 - 15
Rapid Cooling Fans	Provide cooling air at ambient temperature to enable cooling of ware at kiln exit in the 500 - 300 ^{0}C range.	5 - 7
Recuperation Fans	Provide secondary warmed air for burner operation.	3 - 5
Final Cooling	Lower power fans to remove heat from ware at temperatures below 300 ^{0}C.	4 - 8
Air Jet Fans	Insert air into kiln in order to provide the desired oxygen levels to optimise firing.	1 - 3
Undercar Cooling	Further assist the cooling of ware as it leaves kiln.	1.5 - 4

Table 9.17 : Fan Ratings & Descriptions on Tunnel Kilns.

Table 9.17 reveals the kW range and utilisation area of electricity within the firing process.

DSM Options for the Firing Process

The fuel split on gas-fired sanitaryware tunnel kilns is between 6:1 and 20:1 on a gas:electricity basis. For intermittent kilns the ratio range is 20:1 to 30:1 on the same basis. As such, DSM options for firing are likely to impact upon gas utilisation and costs to a significant extent. However, it should be remembered that with a gas to electricity cost ratio of 1:6 at the time of writing (0.6p/kWh to 4p/kWh) that cost savings are not proportional to absolute energy savings.

On the vast majority of sanitaryware kilns, the entire electrical load relates to that consumed by induction motors for fan applications. As electric motors represent the major energy consumption of the firing process, DSM options relate primarily to the use of Higher Efficiency Motors (HEMs) and Variable Speed Drives (VSDs). Appendix A shows a tunnel kiln load profile. Older tunnel kilns, with minimal fan numbers, have been found to exist in the sanitaryware sector. These kilns would benefit greatly in terms of improved fuel efficiency, and greater throughput rates, if a number of fans were retrofitted to provide an upgraded equivalent to more modern tunnel kilns.

HEM's do not offer great potential for the reduction of electrical demand, typically 2-4%, but are particularly attractive from an energy consumption viewpoint. This is highlighted when considering those motors which have high levels of utilisation, which is applicable to all of the motors on modern tunnel kilns. The potential for application of HEM's is considerable, with many manufacturers of sanitaryware not being aware of the recent convergence of price between HEM's and standard motors.

Speed control on motor applications in materials preparation would appear not to have been fully considered by manufacturers in the firing process of the sanitaryware sector. There is little evidence of exploratory work on the feasibility of applying VSD application to tunnel kiln exhaust motors for the purpose of kiln atmosphere control. Conversations with plant operatives have revealed that considerable reassurance would be required with regards to product quality and flexibility in order to consider the application of speed control. If speed control were to prove to be feasible, the main cost savings benefits would be provided through reduced gas consumption. Table 9.18 reveals the DSM options available to the firing process.

DSM Technology	Application Area	Load Growth	Peak Reduction	Load Leveling	Valley Filling	Conservation	Dynamic Load Shaping
HEMs	All motors within tunnel & intermittent kilns.	×	×	×	×	✓✓	×
VSDs	Potential on exhaust fan motors of tunnel & intermittent kilns.	×	×	×	×	✓✓	×
Filter Maintenance	Air inlet filters.	×	×	×	×	✓✓ (✓✓)	×
Heat Recovery	Recovery of heat from firing for drying/shop heating	✓	×	×	×	(✓✓)	×
Dual Fuel Firing.	Alternative firing technique utilising MW for initial 1-2 hrs of firing cycle.	✓✓	×	×	×	(✓✓)	×
Microwave Firing	Alternative firing technique. MW across entire firing cycle.	✓✓	×	×	×	(✓✓)	×

Table 9.18 : DSM Opportunities within the Firing Process

Technology Applicable for Load Shaping Objective ✓✓; Technology Conditionally Able to Deliver Load Shaping Objective {✓}; Applicable to Gas (✓); Technology not Applicable for Load Shaping Objective ×.

Heat recovery from kilns, intermittent and tunnel types, should only be considered when it can be proven that the kiln in question is running to optimum efficiency. Modern kilns are designed to make maximised utilisation of kiln 'waste' heat through pre-heating of inlet air and burner air. Well designed and operated tunnel kilns should in particular have minimal heat for recovery (131).

Intermittent kilns are restricted in terms of heat recovery by their fluctuating levels of heat availability. However, a Department of the Environment 'Energy Efficiency Best Practice' document has revealed that a number of staggered intermittent kilns can be linked to a heat exchanger in order to provide a constant heat source.

Where excess heat is available from tunnel kilns then consideration should be given to installing heat recovery equipment to assist in drying or water heating. This may be particularly favourable for sanitaryware manufacturers who utilise shop drying techniques. Electrical loading is likely to increase when utilising heat recovery, due to the need to use fan power to transport heat through ducting. Heat recovery has been found on four (thirty per cent of) sites visited during this survey. However, most of the sites that utilised heat recovery from kilns have experienced significant problems with fouling of heat exchangers and, as a result, only one manufacturer now utilises heat recovery. This is done to heat water and provide drying heat. Despite this, it must be noted that the majority of the heat recovery systems were installed approximately ten years ago. In response to this heat exchanger plates are now more advanced and offer significant improvement over those installed in surveyed sanitaryware sites.

An alternative to the gas firing of sanitaryware arises in the form of dual-fuel firing. In this technique microwaves are used for the first quarter of the firing cycle in order to facilitate the uniform, rapid heating of the ware. The benefits of microwave firing are increased throughput, as firing cycles are reduced by a factor of four, energy savings of seventy per cent, equating to a forty per cent cost saving, reduced harmful emissions, and improved mechanical properties. Electrical load is increased significantly compared to a gas-only kiln in the initial stages of the firing cycle.

Cost Appraisal

A cost appraisal of several of the devices applicable to the firing process of a typical tunnel kiln within sanitaryware manufacture is given in Table 9.19. These figures are based upon a sanitaryware site producing 10,000 pieces per week, spread over three kilns.

	% Total Site Consumption	% Process Consumption	Operating Cost (£k/yr)
Firing	**28 %**	-	**62**
Extract Fans	**2.8 %**	**10.0 %**	**6.2**
Burner Fans	**2.8 %**	**10.0 %**	**6.2**
Rapid Cooling Fans	**1.8 %**	**7.0 %**	**4.34**
Final Cooling	**5.2 %**	**19.7 %**	**12.2**

Table 9.19 : Relative Electricity Consumption by Process Stage.

The firing process represents twenty eight per cent of the annual electricity consumption of a typical sanitaryware site. Further, electricity consumption has been found to account for twenty per cent of the total energy consumption of the firing process, translating to 25% of energy costs. However, the process has received little attention for the consideration of the installation of energy efficient devices in terms of electricity utilisation, the main thrust being on reducing gas consumption.

From a load shaping/DSM viewpoint the firing process, particularly for tunnel kilns, potential is limited. The majority of motors within a tunnel kiln run continuously, helping to maintain kiln pressure and temperature profile. Intermittent kilns represent greater potential in terms of load shifting, subject to the flexibility of production at individual sites.

However, the extract fan motors of both tunnel and intermittent kilns offer the potential to significantly increase energy and production efficiency of the firing process. Further substantial energy savings can be realised through the application of HEMs to tunnel and intermittent kilns. Table 9.20 shows the cost effectiveness of applicable DSM technologies on identified electric motors within the firing process.

DSM Measure	Application Area	% Change in Process Demand (kW)	% Change in Consumption (kWh)	Cost of Measure (£)	Value of Savings (£/yr)
HEMs	**All motors within kilns.**	(-) 3 - 5 %	(-) 3 - 5 % *	**2265**	**2389**
VSDs	**Exhaust Fans**	(-) 2 %	(-) 20 % (-) 7.5 % *(gas)*	**40 k per kiln.**	**333 (elect)** **16000 (gas)** ***per kiln.***

Table 9.20 : Cost Effectiveness of DSM Measures for Tunnel Kilns; 10k pieces/wk.

** Refers to additional cost above standard motor.*

Table 9.20 reveals that the application of HEMs within the firing process provides significantly cost-effective savings, with a payback of less than one year. This is due to the extremely high utilisation of the motors within kilns.

The application of a VSD to the exhaust fan of a tunnel kiln produces a slightly less favourable payback of just under two and a half years, but does not include the possible benefits from improved product quality and reduced scrap rates.. Within the annual energy savings electricity consumption and demand offer relatively insignificant benefits. However, this is offset by the large savings in gas consumption and the example provides a good demonstration of an option whereby the Supply business of a REC can cultivate an energy service relationship with its customers.

Site Services: Compressed Air Systems

Introduction

Compressed air is utilised in the sanitaryware sector for the purposes of:

- Glaze Spraying
- Pressure Casting - slip pumping
- Manual Casting - slip pumping
- Product Handling

Each sanitaryware manufacturer covered in the survey utilised compressed air to varying extents in relation to these application areas. Thus compressors vary from site to site in terms of size, application, and maintenance levels.

Table 9.21 displays the results of the UK sanitaryware survey. Over ninety per cent of the compressors in operation within the sector are of oil-injected rotary screw type, with capacities ranging between 25 and 300 litres per second, and operating at 7 bar gauge for most applications.

	Rating kW	Cumulative kW	Numbers
Category 1	0 - 50 kW	342	13
Category 2	51 - 100 kW	1033	11
Category 3	101 - 150 kW	1207	11
All Compressors	0 - 150 kW	2582	35

Table 9.21 : Compressors Utilisation within the UK Sanitaryware Sector

Energy Utilisation

The installed compressor capacity within an industrial site is primarily dictated by site production throughput and the technologies utilised. Sites with a high level of throughput will obviously have a higher cumulative kW capacity of compressor(s) than sites with a lower throughput. Specific energy consumptions will, however, differ in accordance with the operating efficiency of the compressors and number of end uses for compressed air, although an average sector SEC for compressors of 0.378 GJ/t, has been derived from a range 0.21 - 0.65 GJ/t. SEC values were derived from capacity ratings on compressors, operating regimes, controls and maintenance levels where actual data was not available. Those sites which utilise pressure casting techniques will typically have an instantaneous demand slightly higher than that for an equivalent level of throughput than a site utilising traditional casting techniques.

Compressors typically account for between four and seven per cent of site annual kWh consumption where pressure casting is not utilised. On sites where pressure casting is utilised, providing an average of five per cent of site throughput, compressors can account for between seven and twelve per cent of annual kWh consumption. In terms of kW demand, compressors can account for between ten and fourteen per cent of cumulative site kW demand. The influencing factors here are type of control and utilisation of pressure casting.

Control of compressor systems within the manufacturing sites visited was seen in almost eighty per cent of cases to be of multi-step unloading type, with modulation at loads of over seventy five per cent. The majority of these were of two-step type, whereby a pressure differential of 0.5 bar operates between full-load and no-load. The modulation control refers to the opening and closing of the inlet valve when the compressor runs at above seventy five per cent load. Only one site in the UK was seen to operate compressors through an advanced micro-computer system.

The 24 hour load profile of a compressed air system operating on a full production day at a sanitaryware manufacturing site, with an average throughput of twelve thousand pieces per week, is shown in Figure 9.12. The profile has been constructed from real-time monitoring of compressor loading.

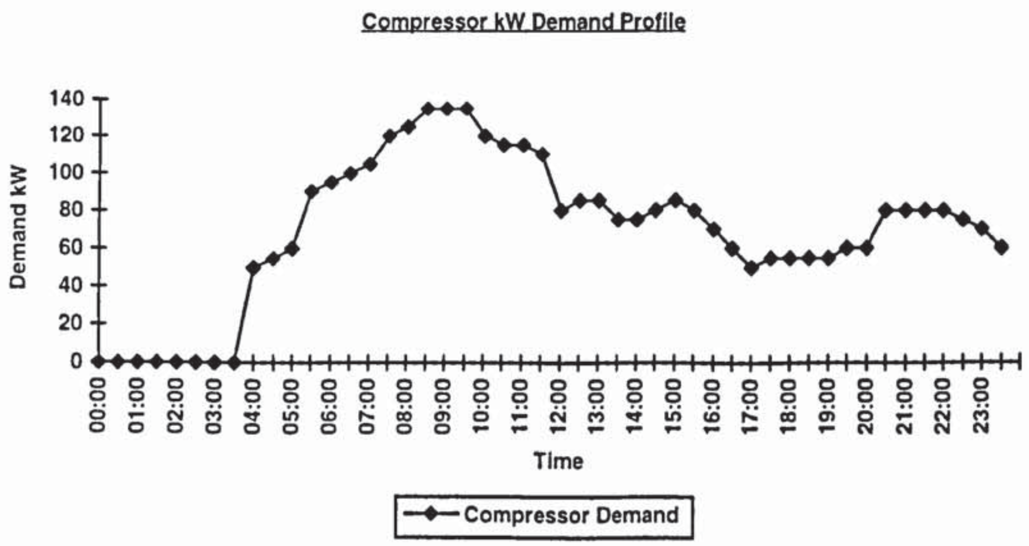

Figure 9.12 : Compressor kW Demand; 12000 pieces per week throughput.

The load profile in Figure 9.12 accounts for double shift operation of pressure casting equipment providing ten per cent of weekly site throughput. The operation of pressure casting machines over a double shift, 16 hour, period is common on sites with pressure casting. This is done in order to provide an higher return on the equipment which is of high capital cost.

DSM Options for Compressed Air Systems

Compressed air systems are generic across all industries in terms of applicable energy efficiency opportunities. The operational efficiency of a compressed air system can be maximised through the analysis of four functional areas. These are:

- Generation
- Distribution
- Leaks
- Use/Misuse

As rotary screw type compressors are by far the dominant type of compressor in use within sanitaryware manufacture the focus will now be on this type.

Generation

The efficiency measures associated with the generation of compressed air are summarised in Table 9.22.

Action	Frequency	Effect	Saving
Pro-active maintenance of compressor unit.	25,000 hrs of operation.	Reduces annual running cost and increases compressor life	Annual running cost saving of up to 5 %.
Power factor correction	Initial.	Reduces kW dissipated relative to kVA applied.	Possible to Reduce demand charges.
Soft starters	Initial	Minimises ware on compressor motor.	Attributable to extended life.
Optimise system pressure	Ongoing	Reduces power consumption by compressor motor.	Annual running cost savings of 5 % for 14 % bar reduction.
Micro-processor control	Initial	Neural network based control to optimise supply and demand.	Reduces consumption by up to 20 %.
Electronic motor control (VSD)	Initial	Matches speed of motor to that of demand.	Reduced consumption by up to 20 %.
Heat recovery	Initial	Partial reclamation of 90 % of the heat generated by compressing air.	Up to £10k savings per year of gas equivalent on a 100 kW compressor.

Table 9.22 : DSM Options for Compressed air Generation (133).

Distribution

Following compression, compressed air is transported to its point of use through pipework. It is essential for pipes, valves etc to be correctly sized in order to maximise efficiency and avoid excess generation to overcome pressure drops. Table 9.23 provides information on the measures available to optimise distribution.

Measure	Action
Configuration	Ring main and grid systems are more efficient than spur arrangements as they provide a more balanced pressure around the site.
Sizing	Air velocities should not exceed 6 metres per second in the main pipe of a system. Pressure drop should be no greater than 0.2 bar at point of delivery.
System Isolation	Manual or electronically controlled valves can shut down supply to areas not utilising compressed air at certain periods
Maintenance	Check pipe systems for leaks.

Table 9.23 : Distribution Measures for Compressed Air Systems (133)

Leakage

Leakage represents the largest area of wastage on a typical compressed air system. An average system loses 30% of demand through leakage (133), with up to 70% being measured at some sites (133). Leakage will often occur in the following areas:

- Condensate traps
- Pipework
- Fittings & flanges
- Manifolds
- Flexible hoses
- Filters
- Tools

(133)

Leakage should be tested for at six month intervals. A large manufacturing site with a large distribution system and many connections can not realistically achieve less than 15% leakage rate, although smaller manufacturers should manage a 5% leakage rate (133).

Use/Misuse

The misuse of compressed air relates to the pressure at which it is being utilised. The sanitaryware industry typically pumps compressed air at 7 bar, however not all end-use applications require this pressure. For example, glaze spraying can be carried out at pressures of around 3 bar, whilst some sanitaryware sites used compressed air lines to blow down slip lines and for slip agitation.

The use of boosters and multiple compressors can enable the wastage of compressed air to be reduced considerably. A 3 bar compressor will typically generate at 275 j/l, 33% less than one generating at 7 bar (133).

An additional DSM option is that of compressed air storage. This technology allows compressed air to be stored after being generated off-peak, usually overnight, and utilised as required over the production day. As such, a significant part of site demand could be shifted to other periods to provide electricity companies with a degree of flexible load shifting.

	Application Area	Load Growth	Peak Reduction	Load Leveling	Valley Filling	Conservation	Dynamic Load Shaping
HEMs	Compressor motors.	×	×	×	×	✓✓	×
Optimised Generation	Pro-active maintenance and control on compressor unit.	×	×	×	×	✓✓	×
Optimised Distribution	Correct sizing of pipes and valves to minimise excessive generation	×	×	×	×	✓✓	×
Leakage	Six monthly checking of pipes etc for leakage of air	×	×	×	×	✓✓	×
Compressed Air Storage	Six monthly checking of pipes etc for leakage of air	×	×	✓✓	×	×	×

Table 9.24 : DSM Options for Compressed Air Systems.

The DSM options identified for compressed air systems in Table 9.24 are not exclusive to the sanitaryware industry and can be applied across all sectors of the industrial market.

Cost Appraisal

A cost appraisal of some of the measures identified have been applied to a typical compressor system in operation at a surveyed sanitaryware manufacturing site. The details of the system are shown below:

	Rating kW	Consumption MWh/yr	Annual Operating Cost £k/yr
Compressor System	133	483	15.47

Table 9.25 : Compressor System Electricity Consumption and Running Costs

The analysis of cost effectiveness is provided in Table 9.26.

	Application Area	% Change in kW Demand	% Change in kWh Consumption	Cost (£)	Value of Savings (£k/yr)
HEMs	Compressor motors.	**(-) 3-5**	**(-) 3-5**	**0.79**	**0.62**
Optimised Control	Pro-active maintenance and control on compressor unit.	**(-) 3-20**	**15**	**7.50**	**2.30**
Optimised Distributio n & Leakage	Correct sizing of pipes and valves to minimise excessive generation. Reduce leakage.	**(-) 3 - 20**	**15**	**1.0**	**3.10**

Table 9.26 : Analysis of Cost Effective Measures for Compressor Systems

Compressed air storage is not considered in Table 9.26 due to a lack of available information on the costs and benefits of the technique. However, in any future calculation it would be necessary to include the avoided costs of network reinforcement associated with its utilisation as a DSM measure. The costs of improved distribution and leakage loss represent the costs of hiring equipment and in-house labour costs.

Lighting

Lighting represents another area of electricity utilisation which varies considerably in terms of proportional kW demand and electrical SEC. Again, factors other than throughput such as site layout, levels of natural lighting, and company policy impact greatly on overall kW demand. Lighting was seen through the survey to vary in terms of SEC from 0.43-1.48 GJ/t, and from 7-25 per cent of annual kWh consumption. In terms of instantaneous demand the lighting load across all sites surveyed ranged from an average of 12-33 per cent of total site kW demand.

Chapter 10

DSM Cost/Benefit Analysis in the Sanitaryware Sector

Introduction

This chapter utilises the end-use technology data obtained from the audit of the UK sanitaryware sector. The data is used to provide a detailed cost-benefit analysis of the potential for DSM within the sanitaryware sector. The work reveals the extent of opportunities for generic technologies and for those of a more sector-specific nature.

The cost analysis undertaken here focuses upon a sanitaryware manufacturer producing approximately 10,000 pieces per week. Prior work carried out in Chapter 9 revealed the extent to which the UK sanitaryware industry can be considered as having generic technology applications, suggesting that relatively large electricity savings could be achieved. The cost-benefit of installing identified technologies is now considered.

Site Details

The manufacturing site which is the subject of this work produces approximately 10,000 pieces of sanitaryware per five day working week. The site has an annual maximum demand of nearly 1.2 MW and an annual electricity consumption of approximately 6390 MWh, costing some £245,000 per annum. The site is supplied on a real-time tariff, purchasing its energy directly from the England and Wales electricity Pool, but shows no sign of managing load in response to the price signals inherent in the Pool system. Figure 10.1 shows the typical daily demand associated with the site and an average Pool purchase cost profile.

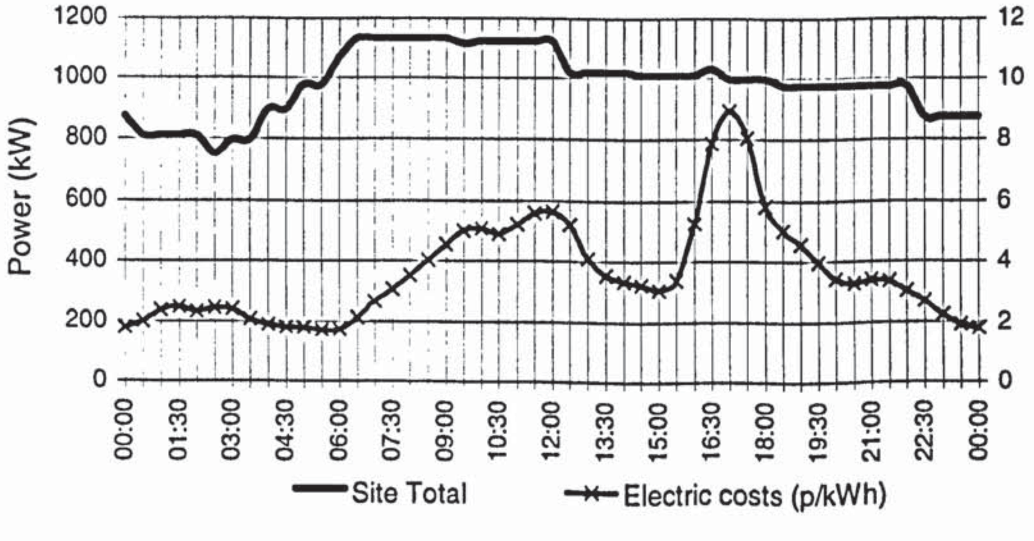

Figure 10.1 : Site Power Demand and Electricity Cost Profile

The annual electricity bill can be broken down into its component parts, namely generation, transmission, distribution and supply. Figure 10.2 shows the relative proportion expended on each area.

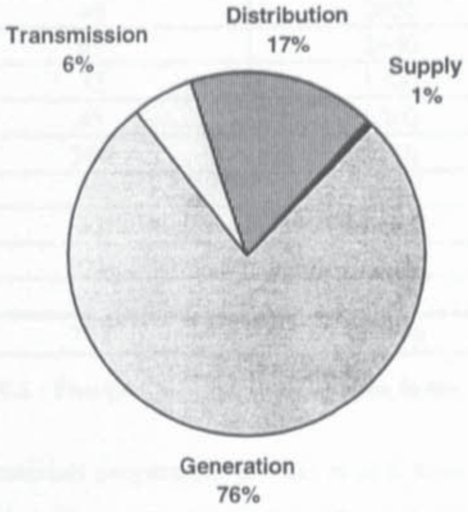

Figure 10.2 : Cost Components on a Unit of Electricity Supplied to Sites in the 1MW Market

On the basis of the above, a REC undertaking DSM can use the avoided costs of electricity purchase as that against which to estimate the cost-benefit of DSM measures. Assuming that the cost of generation is that associated with the marginal purchase of electricity, notionally from the pool, then the avoided cost of purchase relates to generation and transmission costs. This can equate to almost 80% of the cost of a unit of electricity. Further, the volume driver on distribution means that a REC would only lose 50% of the revenue associated with the reduced load. This reduces the amount of revenue a REC would need to recover in order to remain revenue neutral in the case of reduced sales. The site is now analysed in order to identify relevant DSM costs and benefits.

Site Process Areas

The majority of electricity consumption is associated with induction motors, with relatively little utilised for process heating and cooling. Each process area is summarised in terms of electricity consumption by end-use device, and the associated cost, below.

1. Materials Preparation

The materials preparation process consumes 708 MWh of electricity per annum at a cost of £27,490. Technology consumptions and costs are shown in Table 10.1.

	Electricity Consumption (MWh/yr)	Total Annual Operating Cost (£/yr)	Operating Cost per Motor/Device (£/yr)
Ball Clay Tanks	61	2240	1120
Motor Loader	3	120	117
Blungers	48	2020	673
Underground Stirrers	69	2840	355
Pumps to Sifters	32	1300	651
Fine Arc Pumps	45	1840	919
Casting Tanks	248	9180	3060
Casting Slip Pumps (1)	98	3360	841
Casting Slip Pumps (2)	32	1300	651
Waste Blunger	63	2920	2915
Waste Pumps	9	370	184
Total	**708**	**27490**	

Table 10.1 : Energy Costs and Consumption in the Materials Preparation Process

Electricity demand within the materials preparation process is at a peak from 06:00hrs to 12:00 hrs, falling to an average of 38% of peak outside this period. The weighted average cost of electricity associated with the materials preparation process is less than that of site due the larger than average number of units consumed in lower price periods (Figure 10.1).

2. Casting

The casting process consumes relatively minimal amounts of energy within the manufacturing process. Total consumption associated with the process is only 27 MWh per year at a cost of £1,120. The casting process is ruled out from any participation in a DSM programme on the grounds of its minimal consequence and limited potential.

3. Drying

The drying process consumes some 417 MWh of electricity per annum at a cost of £16,520. The end-use technologies within the drying process and their energy consumptions and costs are shown in Table 10.2.

	Electricity Consumption (MWh/yr)	**Total Annual Operating Cost (£/yr)**	**Operating Cost per Motor/Device (£/yr)**
L2 Fan Inlet	61	2240	2240
L2 Fan Extract	17	610	610
L2 Fan Heat	21	920	920
Dryflex	115	4530	4530
Ware Dryer	25	1000	1000
U/B Fans	36	1570	33
O/H Fans L3	8	320	3
O/H Fans L4	10	430	3
Mould Dryer	83	306	3060
Total	**417**	**16520**	

Table 10.2 : Energy Costs and Consumption in the Drying Process

The electricity demand profile associated with the drying process is primarily driven during off-peak periods, reflecting the practice of 'shop-drying'.

The drying process accounts for almost 12% of site electricity consumption yet represents almost 20% of overnight demand. This level of demand highlights the potential benefits of targeting the drying process where DSM is focusing upon reducing off-peak demand yet dictates that the process will have lower avoidable costs due to its access to off-peak lower cost electricity. This is explored further in

4. Firing

The firing process consumes nearly 2200 MWh of electricity per annum at a cost of nearly £79,000, mainly in kiln fans. The end-use technologies within the firing process and their energy consumptions and costs are shown in Table 10.3.

	Electricity Consumption (MWh/yr)	Total Annual Operating Cost (£/yr)	Operating Cost per Motor/Device (£/yr)
Extract Fans	174	6430	2142
Refire Extract	85	3140	3142
Burner Fans	185	6860	857
Burner Fans	464	17140	4285
Rapid Cooling Fans	124	4570	1143
Recup. Fans (1st Fire)	128	4710	1571
Recup. Fans	185	6860	857
Refire Recirc.	58	2140	2142
Final Cooling	340	12570	3142
Air Jet Fans	70	2570	857
Refire Air Jet Fans	46	1710	857
Undercar Cooling	185	6860	857
Total	21116	78200	

Table 10.3 : Energy Costs and Consumption in the Firing Process

The electricity demand profile associated with the firing process is predominantly flat, reflecting the large number of constant speed motor applications on fans. The contribution of firing to the site demand profile can range from 20-35%, the higher end of this range being seen overnight.

Site Services

The site services within the site relate primarily to lighting and compressors. Combined, these account for 1497 MWh of electricity consumption per annum, at a cost of £74,650. These figures represent almost 25% and 20% of site consumption and cost respectively. Lighting drives these relative figures, primarily due to the poor management of lighting costs and control, shown through lighting running for almost 24 hours per day throughout the year. Table 10.4 shows the end-use technologies associated with lighting and compressed air and their electricity costs and consumptions.

	Electricity Consumption MWh/yr	Annual Total Operating Cost - £/yr	Individual Device Operating Cost - £/yr
Lighting	1510	55820	35
Compressors	472	18550	14271

Table 10.4 : Energy Costs and Consumption in Site Services

Cost Appraisal Under DSM Scenario

The application of DSM to the process areas, as outlined above, is now considered, providing an analysis of the costs and benefits that could be expected from DSM programmes initiated by the host REC. The DSM options across all process areas, the generic technologies, primarily relate to HEMs, VSDs, and motor optimisers. Other technologies are more process specific.

Analysis of Cost Effective Measures

Motors

Standard motors are responsible for almost 80%, 4513MWh, of total site electricity consumption. Many of these motors run for long hours and at high loads. The replacement of standard motors by HEMs has been analysed. The incremental cost of a HEM over a standard equivalent has been used as the capital cost against which to offset energy cost savings. A payback of 3.5 years was set as a first-order measure of cost-effectiveness, followed by a NPV calculation on viable motors over a 5 year operating period, taken as the lifetime of the motor. A discount rate of 8% real was used.

The cost-effectiveness of HEM installation on viable motors was considered under two scenarios. The first was as a stand-alone investment by the manufacturer in question, whereby the full value of energy savings are recovered. The second scenario examined the cost-effectiveness of the same investments when considered under the DSM scenario, whereby the sponsoring REC would examine the investment in 'avoidable cost' terms i.e. the REC would attribute cost-savings to those associated essentially with generation, transmission. Table 10.5 shows the results.

	Total Capital Cost (£)	Savings (£/yr)	Savings DSM (£/yr)	Payback (yrs)	Payback DSM	NPV 5yrs	NPV 5yrs DSM
Lighting							
Slip Preparation	850	791	653	1.7	2.0	2871	2231
Glaze Preparation	150	103	85	1.5	1.8	336	253
Drying	280	494	408	1.2	1.5	2026	1626
Ventilation	2065	1588	1310	1.4	1.7	5430	4146
Compressors	798	742	612	1.0	1.3	2691	2091
Tunnel Kilns	2580	3022	2493	0.9	1.0	11582	9137
Intermittent Kilns	125	106	87	1.2	1.4	375	289
Casting							
Total	6848	6847	5649	1.3	1.5	25312	19773

Table 10.5 : Comparative Avoided Costs Under Consumer and DSM Driven Investment in HEMs

The HEM investment is very attractive from the manufacturer's viewpoint, with investments paid back in an average of 1.3 years and a NPV after 5 years of over £20,000.

Equivalent analysis is shown in Tables 10.6 and 10.7 for VSDs and Soft-Starter/Optimisers. For VSDs and Soft-Starters a viable payback period of 4 years was utilised in order to reflect the more capital intensive nature of such technologies. Measures taken are allocated a lifespan of 5 years.

	Total Capital Cost (£)	Savings (£/yr)	Savings DSM (£/yr)	Payback (yrs)	Payback DSM	NPV 5yrs	NPV 5yrs DSM
Lighting							
Slip Preparation	6000	1515	1514	4.0	4.0	2933	1448
Glaze Preparation	n/a						
Drying	n/a						
Ventilation	17600	5876	4848	3.0	3.6	10868	6114
Compressors	n/a						
Tunnel Kilns	2580	1657	1367	2.9	3.5	3289	1948
Intermittent Kilns	n/a						
Casting							
Total	28320	9047.8	7730	3.3	3.7	17090	9510

Table 10.6 : Comparative Avoided Costs Under Consumer and DSM Driven Investment in VSDs

Investments in VSDs are particularly attractive in the ventilation and kilning processes. VSD application in the materials preparation area, although suggested as being cost-effective, is deemed to be not technically viable at present.

Despite the opportunities to implement VSDs, VSD application per se by the manufacturer without assistance is doubtful. The majority of VSDs are applicable to tunnel kilns, and as such are seen by manufacturers as high risk in terms of potential savings and impact on product quality during commissioning. As such, capital cost support and monitoring/savings verification would be essential deliverables of DSM in this area.

	Total Capital Cost (£)	Savings (£/yr)	Savings DSM (£/yr)	Payback (yrs)	Payback DSM	NPV 5yrs	NPV 5yrs DSM
Lighting							
Slip Preparation	450	204	168	2.2	2.7	526	361
Glaze Preparation	300	180	148	1.7	2.0	554	408
Drying	225	70	58	3.3	3.9	114	56
Ventilation							
Compressors	1995	1299	1071	1.5	1.9	4156	3105
Tunnel Kilns	0						
Intermittent Kilns	0						
Total	2970	1752	1445	1.8	2.6	5350	3930

Table 10.7 : Comparative Avoided Costs Under Consumer and DSM Driven Investment in Optimisers

Table 10.7 also suggests scope for cost-effective energy savings within the manufacturing process. However, the most attractive investment area of compressors showed conflict with a cascading control device already in place and awaiting re-commissioning. Other opportunities in Glaze and Materials Preparation were seen as technically doubtful.

Other Technology Specific Measures

The application of DSM technologies can reduce gas costs as well as those of electricity, providing further opportunities for the attainment of DSM objectives. Table 10.8 displays the cost analysis of some of the measures considered.

	Gas Consumption (GWh/yr)	Electricity Consumption (GWh)	Capital Cost (£k)	Value of Savings (£k/yr)	Payback (yrs)
Tunnel Kiln Exhaust Fan Control	34.32	0.06	40 per kiln	57.4 per kiln	2.1
Intermittent Kiln Exhaust Fan Control	3.4	0.04	10 per kiln	7.7 per kiln	2.6
Compressor Control System	0	0.47	7.5	2.8	2.7
Airless Drying	1.5	0.08	100	12.7	0.7
Dryer Control System	1.5	0.08	10	4.6	2.1

Table 10.8 : Costs Savings of Miscellaneous DSM Investment Measures

These technologies are summarised:

- **Improved Tunnel Kiln Exhaust Fan Control**

  This technology is designed to improve control of kiln atmosphere, saving exhaust fan power and gas. Electricity consumption is estimated to reduce by 20%, with gas consumption reduced by 7.5%. Product quality improvements are delivered through closer matching of glaze finishes in terms of colour consistency. Estimated cost of a control system is put at £40,000, with energy savings delivering a payback of around two years, not including the cost of reduced rejection rates.

- **Intermittent Kiln Exhaust Fan Control**

  This technique also uses VSD control on the exhaust fan to control kiln pressure throughout the firing cycle. As with tunnel kilns, savings are delivered through reduced electricity and gas consumption. However, the two intermittent kilns in operation at the site were old and did not justify the initial capital outlay.

- **Compressor Control Systems**

  Improvements to compressor efficiency have been addressed in a minor way through the analysis of HEMs and Optimisers. Table 10.8 shows the cost-benefit of taking additional measures to improve compressors efficiency. These are through increasing compressor maintenance and through re-establishing the cascade control system. The site being analysed here was considering its usage of compressed air and trying to identify the scope for further improvements. RECs have expertise in this area and, considering the lack of such expertise in-house, there was an opportunity for REC involvement in this project.

- **Drying Systems**

  Airless drying could be utilised as an alternative drying process to shop-drying. The superior control available through the use of a dedicated drying system such as airless drying can offer substantial savings over traditional shop-drying. Electricity and gas consumption could theoretically be reduced by 20% and 10% respectively per annum. This equates to a payback of approximately 2 years.

Potential of All Identified Measures

The analysis of the cost-effective savings available on the site has revealed that up to 10%, or 100 kW, of site demand can be reduced across the entire site profile. Nearly 4% of this demand is attributable to the installation of cost-effective HEM's, the remainder being associated with the installation of VSDs on motors utilised for ventilation, drying and firing. Major process changes have been limited to that of retrofitting equipment to enable tunnel kiln exhaust control, with potential improvements in product quality and reduced gas consumption over-riding the benefits of achievements in reduced electricity consumption. Further substantial demand and consumption reductions can be made through re-establishing control systems on the compressors and increasing maintenance levels. Figure 10.3 shows the revised site load after identified measures have been installed.

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Figure 10.3 : DSM Adjusted Demand and Cost Profiles

The cost-effectiveness of measures on a cost-saving basis is reduced when considering the DSM scenario. This is due to avoided costs being reduced when compared to those that would be seen by the end-user who undertakes the investment without REC intervention/subsidisation. REC involvement in energy efficiency reduces avoidable costs when the REC desires to maintain DUoS revenues accruing from an existing asset.

However, the main cost-saving benefit from the REC perspective is that associated with the deferral of capital expenditure. This relates to the actual revenues that can be attained from capital available to invest elsewhere and to the non-committal nature of DSM investment. As DSM expenditure is relatively low and incremental, particularly when compared to that the high investment and 'sunk' costs associated with network reinforcement, the scope for 'stranded assets' is lower. It is the monetary value associated with this deferred investment that drives the ability of a REC to invest in DSM. The benefit of this to REC and customer is now considered, using the site analysed previously to illustrate the example.

Impact of REC Intervention Through DSM

Preliminary analysis has shown that there are cost-effective opportunities for energy efficiency on the manufacturing site. However, not all cost-effective energy efficiency investment is undertaken for numerous reasons discussed in Chapter 11.

Tables 10.5-10.7 reveal that the lower avoidable costs when considering DSM result in lower project returns and more demanding payback criteria. This is due to the REC seeking to recover DUoS charges, if at all possible, when considering the financing of DSM. However, it is under the DSM scenario that the REC is able to contribute towards the cost of energy efficiency to reach a win-win situation with the customer, the contributions being funded through the avoidance of capital expenditure on reinforcement.

Investment Appraisal Under DSM

The scenario considered here requires DSM investment to reduce the load on a substation where peak demand is driving reinforcement costs. The substation is assumed to have a maximum demand rating of 30 MVA which is currently operating at a 65% load factor. The substation maximum demand of 30 MVA is reached for a continuous period of 5 hours per day for 120 days per year. It is assumed that:

- Investment costs are £750,000, providing a 25yr life on new assets. There is no residual value at the end of 25 years.
- A discount rate of 8% real is used for reinforcement costs and DUoS revenues.
- The substation has an underlying demand growth of 2% per year across all periods.
- The average revenue received from sales is 3.7p/kWh, the substation being directly connected to a large industrial estate.
- Average DUoS revenue is equivalent to 0.4p/kWh, with the distribution volume driver being 50% of allowable revenue.
- Annual sales associated with the transformer are 170 Gwh.
- All DSM measures expire at the end of year 6.

The site analysed for this example has a maximum demand of 1.2MW, contributing 1.2MW of demand to the substation at time of system peak i.e. for 5 hours of 120 days.

Traditionally, a REC would upgrade the substation, spending £750,000. The REC would then accrue DUoS revenue over the life of the asset, recovering the cost of the investment and providing a return to shareholders. Under this scenario, the NPV of the investment would equate to nearly £813,000 after 25 years, considering only the increased DUoS revenues associated with the new substation.

Alternatively, the REC can choose to undertake DSM measures to postpone the investment, accruing benefit from the extended asset life and deferral of capital expenditure. Under this scenario, the deferred investment of £750,000 is assumed to return £75,000 per annum for six years. At the end of six years the REC is deemed to face no option other than to replace the existing transformer arrangement due to the age of the equipment and increased demand levels of peripheral load. Under this option, the NPV of the revenue stream after 6 years, including lost DUoS revenue, is £313,000. Over 6 years the required reduction in energy supplied is 5546 MWh. On this basis, it is viable for the REC to spend up to £56/MWh (5.6p/kWh) on reducing load associated with driving reinforcement costs and still be better off than under traditional reinforcement.

The site analysed in this example was identified as having opportunities in several generic technology areas. These opportunities are deemed to deliver a 100kW reduction in load across all time periods, not only at times of peak demand that are targeted by the DSM programme. The cost analysis presented here assumes that the sponsoring REC is willing to subsidise the cost-effective measures identified in the areas of HEMs, VSDs and motor optimisers, with a 50% rebate on capital costs. The cashflows and NPV associated with these DSM costs is shown in Table 10.9.

	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	NPV
Monitoring & Targeting (£)	2,500	2,500	2,500	2,500	2,500	2,500	**10888**
Administration	600	600	600	600	600	600	**2613**
Capital Cost: HEMs	3,400	-	-	-	-	-	**3400**
Capital Cost: VSDs	14,000	-	-	-	-	-	**14000**
Capital Cost: Optimisers	750	-	-	-	-	-	**750**
Total	**21,250**	**3,100**	**3,100**	**3,100**	**3,100**	**3,100**	**31,651**

Table 10.9 : NPV of the Costs of the DSM Investment Programme

Table 10.9 reveals a NPV of the DSM programme of £31,651. This cost is made by the REC in an attempt to reduce demand at time of system peak by 100kW, equating to 360 MWh over the residual life of the existing substation. This provides a cost of nearly £88/MWh compared to the maximum allowable of £56/MWh, £32/MWh over allowable costs. Under this scenario, the customer benefits are highlighted in Table 10.10.

	Total Capital Cost (£)	Subsidy (%)	Payback (yrs)	NPV 5yrs
HEMs	6848		1.3	20998
HEMs (with DSM)	3424	50	0.8	23000
VSDs	28320		3.3	9903
VSDs (with DSM)	17100	40	2.5	18889
Optimisers	2970		1.8	4246
Optimisers (with DSM)	1485	50	1.1	5308

Table 10.10 : Customer Benefits of Participation in DSM Programme

The site, assuming subsidisation of capital costs of 50%, experiences superior returns on initial investments, lowering payback period and increasing NPV. Obviously, under this scenario and level of rebate, DSM is very beneficial to the REC's customer. The payback figure with the DSM recovery includes the recovery of DUoS revenue.

The REC position under the DSM scenario after 25 years, the same period of time as that used for the traditional investment evaluation, delivers a NPV of £1.5m. This increase in revenue over that of the traditional investment is partly achievable due to the increased load factor over the lifespan of the deferred substation (the increased revenue may even be understated as the substation has a residual life of five years after 25 years in this investment comparison). Under this scenario, the REC would be able to spend up to £650,000 on the DSM option (up to 10p/kWh). This would then make the cost of £88/MWh for site measures more favourable, however, it does assume that the REC is undertaking DSM for no real financial benefit if all measures were this expensive.

It is unlikely that a sponsoring REC would undertake DSM without substantial reward due to perceived risks that are above those of supply side investment. For example, if the sponsoring REC decided that it required 50% of the increased revenues then the maximum cost of a unit saved would be nearer £50/MWh, ruling out the participation of the sanitaryware sector at the level of capital cost subsidisation (50%) used here.

The Costs and Benefits of DSM in Sanitaryware Manufacture

The example highlights the sensitivity of the DSM project when considering elements such as the timing of investment and the perceived reward required by a REC sponsoring DSM. DSM is driven by avoidable costs and accrued benefits. Under the scenario adopted above the costs of applying DSM to the sanitaryware site, attempting to make use of all viable cost-effective measures, resulted in REC costs exceeding benefits by over £30/MWh (3.0p/kWh).

This can be explained by the relatively short duration of the peak (7% of time over one year), which dictates that those energy efficiency measures that have high utilisation times should be avoided. Unfortunately, many of the measures available to influence demand within the sanitaryware sector have high utilisation levels that make the sector sub-optimal in terms of being suitable for peak lopping.

Despite this, at an end-use device level some investments will be more cost-effective than others and, assuming knowledge is available, the relevant devices can be targeted. It is the detailed knowledge of end-use devices and operating times that focuses DSM appraisal and can help to ensure an optimal outcome for any DSM program. For example, targeting a 25kW motor operating only in the required 5 hour period but for 120 days per year would yield a DSM cost of only £36.6/MWh, nearly £20/MWh below the maximum allowable cost of the above appraisal.

On the basis of the above, making a judgment on the value of the sanitaryware sector in terms of its potential for DSM programme participation is difficult. Most DSM programmes will be unique and transient in nature, requiring each programme to be appraised in isolation in terms of likely participants from certain subsectors. Going beyond general suggestions regarding the relative levels of load and numbers of devices of high/low utilisation when attempting to state whether a particular sector of industry should or should not be considered useful for DSM is difficult. The answer is, in essence, driven by the nature of the question.

CHAPTER 11

SEGMENTING THE INDUSTRIAL MARKET FOR DSM

Introduction

The division of the REC business in England and Wales has brought about two very different areas of business known as Distribution and Supply. Distribution continues to be regulated whilst electricity supply, already competitive in the markets for customers with a maximum demand of over 100kW, will be fully competitive in 1998.

A major challenge facing electricity supply companies is that of improving margins in what could be a very competitive business. Supply per-se is likely to remain a business of high turnover and low profit margin. Thus, in order to improve these margins electricity suppliers will need to maximise cost reduction. Having achieved this, another opportunity appears for the increasing of supply margins. This opportunity arrives in the form of Energy Services or Energy Procurement Contracts (EPCs), and offers the ability to optimise DSM programmes to the benefit of the electricity company and the customer.

However having decided to offer Energy Services the question arises as to how will customers perceive such an offering. Will they want to pay a higher rate or fixed charge in order to receive potential benefits of energy efficiency or management? Undoubtedly not all will wish to do so, and there is likely to be an entire spectrum of customer needs in terms of the actual service that they require an electricity supplier to deliver. In order to optimise the offerings of Energy Services or EPCs, electricity suppliers will need to have a deeper and broader understanding of their customers needs than is prevalent at present. Market segmentation offers a route to achieving this level of understanding. Segmentation aims to categorise an essentially heterogeneous market of customers into manageable groupings of customers with similar needs.

In this chapter the process of market segmentation is applied to the ceramics sector. The results of applying this technique are then analysed, and its potential costs and benefits explored.

Market Segmentation

Market segmentation is a fundamental marketing task. Customers within a market for any product or service are very heterogeneous in terms of their absolute needs and requirements. However, the development of a marketing strategy which would be able to satisfy each individual is unrealistic and impossible to manage. In order to overcome this, market segmentation aims to collect together individuals who, although at first appear totally different in terms of what they demand from a particular good or service, actually share underlying similarities on various aspects of the product or good in question. Ultimately, there are assumed to be two criteria for segmentation (19):

- differences between customers in terms of their actual or potential needs from a product or service.

- Differences between what they are willing to pay for a solution to these needs.

In consumer markets, such needs are correlated with income, age, or lifestyle. In industrial markets these needs are often correlated with the industry of the end-user and customer size. It is through segmenting markets that firms are able to meet customers' needs effectively and profitably.

A market segment is a customer group within the market that has certain characteristics which make it stand out form other segments. Segmentation, even in a market where a single product would be able to meet the majority of the needs of customers, is said to be a desirable feature (19). This is by virtue of the segmentation being able to offer the opportunity to increase profit margins as different customers will attach different values to the solution offered. Figure 11.1 gives the benefits of market segmentation.

Why Segment Markets ?

There are several reasons for segmenting a market.

1. **Better Matching of Customer Needs:** Because the needs of customers differ, creating separate offers for each segment provides better solutions. Developing separate 'brands' for each segment allows a higher level of satisfaction for customers.

2. **Enhanced Profits:** Customers differ in their price sensitivities and, through segmentation, the seller is able to raise average prices and thus enhance profits. Marginal revenues from premium brands often far exceed the value added to them. For example, United Distillers created a premium brand of Johnnie Walker Whisky which, although only accounting for 20% of its sales volume on the mass Red Label brand, was estimated as doubling profits on overall sales of Whisky.

3. **Enhanced Opportunities for Retention & Growth:** Segmentation can increase sales growth. By being able to offer products which satisfy customers needs, then a firm can resist cream-skimming by potential rivals. Also, having differing segments allows scope for captured customers to trade up. Many firms now see certain brands as entry level opportunities for customers, giving low margins but offering the opportunity to persuade the customer to 'trade-up' and move to products with much greater margins.

4. **Targeted Communications:** Delivering a clear message to a broad undifferentiated market is difficult. Effective communications which maximise sales potential requires the targeting of particular homogeneous markets.

Figure 11.1 : Benefits of Market Segmentation (19)

Criteria for Segmentation

According to Doyle (19), a segmentation strategy should meet five criteria if it is to be used as a marketing tool.

1. *Effective.* The segments identified should consist of customers whose needs are relatively homogeneous within a segment but significantly different from those in other segments. As an example, an industrial marketer might identify the engineering and aerospace industries as separate segments, but if buyers in both industries purchase similar amounts at similar prices and have the same needs, it is not a useful segmentation scheme.

2. *Identifiable.* The business must be able to identify customers in the proposed segment. It is necessary to find some customer characteristics that link to any constructed profiles.
3. *Profitable.* The more segments that are identified, the greater the opportunity to target the offer precisely and add value. Ultimately each customer could be an individual segment. However, the

greater the number of segments targeted, the higher the costs through diminishing economies of scale.

4. *Accessible.* Customers within the segment should be capable of being reached and served. Communications channels should be established and acted upon accordingly.

5. *Actionable.* A company must be able to take advantage of the segmentation scheme it develops. A scheme with many segments is not a particularly useful one if the company does not have the resources to deliver separate offerings to each segment.

Demand Side Management (DSM) by its very nature depends upon the co-operation of a utility's customers. When targeting DSM programs in the industrial sector it is common for utlities within the UK to employ a blanket approach focusing upon singular issues such as lighting, power factor, or motors (17, 82). However, this approach can lead to sub-optimal participation rates, and thus demand reduction levels, due to its lack of understanding of the customer's outlook towards energy efficiency. It is thought that through being able to offer the customer a DSM program more suitably tailored to what the customer wants, or is prepared to accept, then the success of the program will move further towards an optimum outcome.

The question leading from this is just how do utilities go about trying to identify the aspects of an energy efficient technology or DSM program which appeal to customers. The procedure known as 'cluster analysis' can be utilised as a tool to achieve the goal of market segmentation.

Cluster Analysis

Cluster analysis has been used extensively in many fields of study, for example phsychology, biology, and chemistry, and is a technique through which a number of items are sorted into a smaller number of homogeneous groups.

In the field of market research the technique has found most utilisation in the area of market segmentation (96), but has also been utilised for the grouping of similar products (81), in test market selection (31) and to identify companies pursuing similar strategies (20).

Cluster analysis is an interdependence method whereby the relationships between objects and subjects are explored, with a dependent variable being identified at the outcome of the procedure.

The technique of cluster analysis has leant its title to several related techniques. This problem has been heightened, it is claimed (72), by many authors failing to disclose the exact approach taken, the referral of several names to basically the same approach, and a lack of guidance as to which approach or method works best under a particular situation. As such, cluster analysis has come under criticism from several authors who have expressed reservations over the benefits and reliability of cluster analysis. Authors have, specifically, criticised the inherent difficulty in establishing the appropriate measure of similarity and optimum number of clusters (31).

Despite the criticisms, other authors (72) have defended the technique on the grounds that the problems associated with cluster analysis are inherent within multivariate statistics in general. These problems include: choice of an appropriate measure, selection of variables, cross validation and external validation. Saunders (40), gives a flow chart of the cluster analysis procedure, reproduced in Figure 11.2.

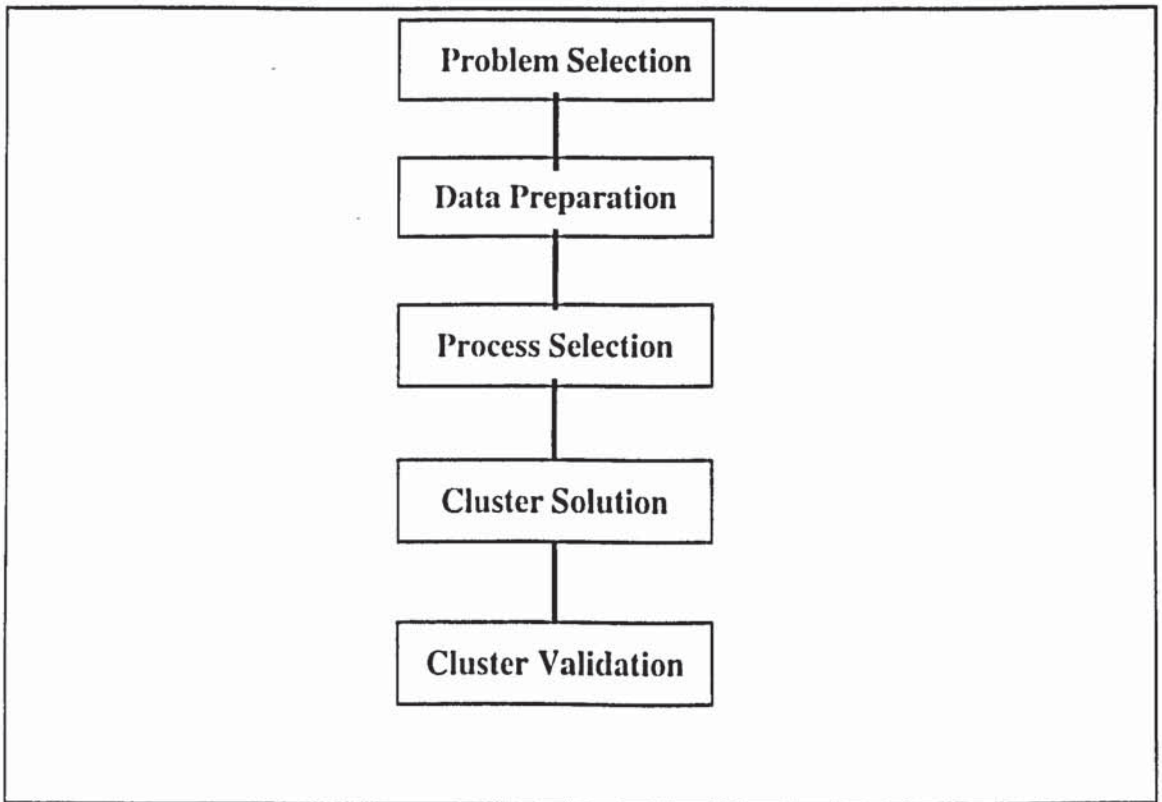

Figure 11.2 : Cluster Analysis Flow Chart (40)

Each of these stages will now be explained in accordance to Saunders (40).

Problem Selection

The literature would suggest that the technique of cluster analysis has been most successfully applied, and most commonly utilised, where interval or ratio scales have been used to gather data (40). Clustering algorithms are available for non-metric data, or a mixture of both non-metric and metric, but are rarely utilised in practice (32).

Saunders recommends caution in the use of cluster analysis, and multivariate statistics in general, due to the ability of many techniques to produce a solution even where one may not naturally exist. Further analysis of the literature reveals the same foreboding from Everitt (23).

In order to minimise the chances of wasted effort in the clustering procedure there are several techniques available to allow the examination of data prior to the clustering. Such techniques include Star Plots, Andrews Plots and Chernoff "facers" (88). All allow visual inspection of a small amount of data for the purpose of looking for natural clustering. However, the necessity of these techniques is open to question when considering the wide range of software packages which can perform cluster analysis at great speed.

Data Preparation

The data preparation stage involves ensuring that all variables utilised in the cluster analysis procedure are relevant. As such, a haphazard approach towards variable selection is to be avoided, and only those variables known to be of relevance through prior hypotheses or visual inspection should be included. Saunders notes that this process is particularly difficult in the case of large databases of variables, and that in such cases the rogue variables are unlikely to be identified until after the analysis has been conducted. In this case the process would become iterative as spurious variables are removed. Punj and Stewart write further on the affects of spurious variables on cluster solutions (40).

Variables used in the cluster analysis can be split into two groups in order to allow cluster validation. One set of the variables is used to form clusters and the other set to validate the results as descriptor variables. It is noted that often the descriptive variables are inappropriate for inclusion in the analysis procedure due to their being measured on a different scale, or of a different type, to the analysis variables (40). As such, the legitimacy of any clusters found is increased through the appearance of differences across descriptor variables as well as analysis variables.

Process Selection

The term 'process selection' refers to the technique to be utilised in order to measure a degree of 'similarity' between observations across the variables tested. Figure 11.3 displays two types of distance measure:

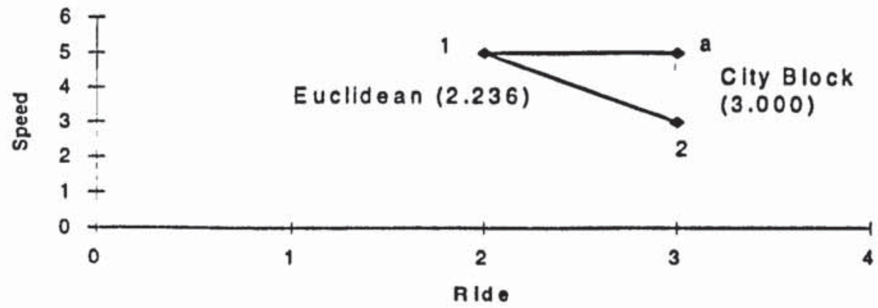

Figure 11.3 : Distance Measures (40)

Euclidean Distance represents the shortest route between 1 and 2, whilst city block moves from 1 to 'a' and then to 2. There are a number of other distance measures open to users of cluster analysis, such as 'Squared Euclidean distance', and 'Chebychev' (170). However, experimentation has shown that whatever distance measure is utilised, the overall influence on the outcome of the cluster analysis is minimal (40). This contrasts with other measures such as similarity, and matching. Similarity and matching measures do, when compared with difference measures, reveal different results.

Similarity represents the attempt to measure the profile of the results, that is they recognise individuals as alike if they give the their highest score to the same variables. Such a technique is represented through the *cosine of vectors of variables* or Cosine rule:

$$\text{Similarity } (X \text{ and } Y) = \frac{\sum_i (X_i Y_i)}{\sqrt{\sum_i (X_i^2) \sum_i (Y_i^2)}}$$

(170)

Despite the number of available measures, users of cluster analysis are rarely seen to now deviate away from Euclidean distance (Saunders):

$$\text{Distance } (X \text{ and } Y) = \sqrt{\sum_i (X_i - Y_i)^2}$$

(170)

The most commonly utilised technique of forming clusters is that of hierarchical cluster analysis. This technique combines observations on the grounds of their similarity by beginning the process with all observations separate as individual clusters, and then combining an observation with another which is most similar to itself. Thus the combined observations form a new cluster, and the process continues.

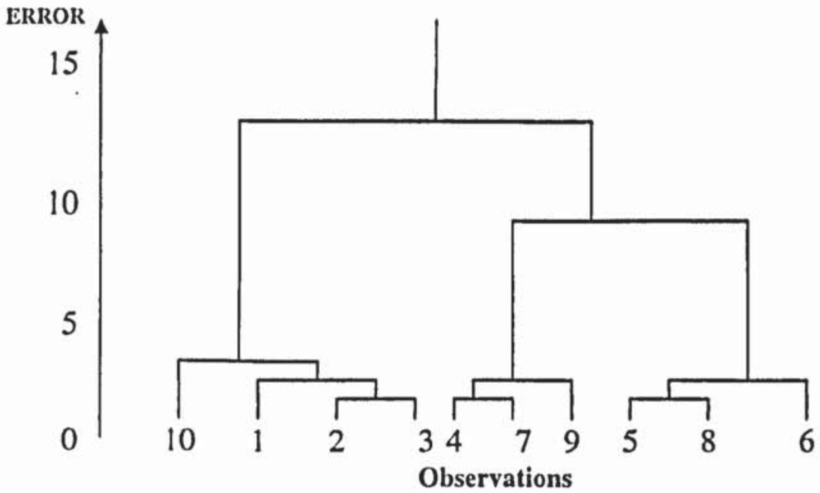

Figure 11.4 : Hierarchical Cluster Analysis (40)

In the dendrogram of Figure 11.4, the vertical axis represents the increasing magnitude of the distance measures, as clusters which are less alike are brought together. Initially the magnitude of error is quite small, becoming larger as observations and cluster of increasing difference are brought together.

The joining of clusters becomes an issue in terms of measuring when clusters should actually be joined. There are many techniques available to facilitate this end. Saunders (40) notes that the algorithm chosen for the purpose of merging cluster has a greater influence over cluster solution than the measure of alikeness between observations. Table 11.1 shows the range of techniques available:

Methods	Aliases
Single Linkage	Connectiveness method, linkage analysis, minimum method and nearest neighbour cluster analysis
Complete Linkage	Diameter method, furthest neighbour method, maximum method and rank order typal analysis
Average Linkage	Centroid method, median method, simple average linkage analysis and weighted average method
Minimum Variance	Error sum of squares method, minimum variance and Ward's method
Partitioning Methods	
K-Means	Density Search
Hill Climbing	

Table 11.1 : Variety of Clustering Techniques (40)

Single Linkage cluster analysis is the most simple technique. In this method an observation is joined to a cluster, giving it a discernible level of alikeness with at least one other member of that cluster. As such, cluster are joined on the basis of links between single entities with the result that clusters appear as a series of stringy overlapping groups. A method of producing more compact groupings is represented through the technique of complete linkage, whereby an observation/cluster is joined to another cluster if the most dissimilar member of the proposed cluster is more similar to the observation than any other cluster.

Another method of clustering is the average linkage approach. Here, a cluster average is computed, and then merged with the observation or cluster which has an average closest to this value. The presence of outlayers, observations that contrast sharply to the observed average, can have significant influences on the results of the clustering procedure, altering the centroid of a cluster if a value is highly deviant. However, the Minimum Variance approach is the most commonly used form of measure. This approach seeks to analyse what happens when an observation/cluster is joined to a cluster, minimising within cluster variance. As a result, clusters produced are of a dense, spherical nature (23). A draw back can occur if natural clusters do not have the form of dense spherical clusters, leading to the possibility of not identifying niche markets.

<u>Cluster Solution</u>

One of the major problems of cluster analysis is the identification of the 'right' number of clusters in a solution. This can be done visually through the use of a dendrogram, as seen if Figure 10.4 previous, where the error appears significant after three clusters have been formed. An alternative is the utilisation of a scree plot, recording the error sum of squares at each stage of the clustering process, and selecting the optimum number of cluster solutions when the error value experiences a significant jump in value.

Despite the numerical approaches depicted above, the real world application of the solution requires a manageable end-point. The identification of thirty clusters may very well be possible through the cluster solution, but would be unmanageable as a business tool. It has been suggested (40) that many companies would find it difficult to manage more than six clusters.

<u>Solution Validation</u>

The validation of market segmentation carried out through cluster analysis can be tested through several methods. Namely *internal, external,* and *operational* validity, and *replicability.*

The operational validity of a cluster solution relates to the degree of utilisation and the feasibility of targeting the market segments developed. This in turn leads to the need to develop techniques with which to assign customers to a particular segment, extending the cluster analysis results to the overall population.

The internal validity of a cluster solution is achieved through the visual inspection of the data collected and which formed the segments. It is possible to do so through multivariate analysis, examining changes in the mean of observations over the variables used in the clustering procedure. The testing of internal validity has been stated as being loaded to a large extent by the prior validation of cluster variables (40).

External validation requires the analysis variables to be split into two groups. The first group then forms the basis of the cluster analysis procedure, and the second group is withheld in order to verify the validity of the clusters produced. It is often the case that the data withheld from the procedure is of a nominal rather than a numerical nature and therefore not valid for the clustering procedure. As such, nominal variables can be, and often are, used as 'descriptors', defining and describing the clusters formed.

Operational Validity

Operational validity represents the final stage of the cluster analysis procedure. On this basis, statistically valid results delivered by the cluster analysis need to be usable. Saunders (QMM) states that this can prove to be difficult in some cases as it requires that the cluster solutions allow the larger population to be readily allocated to their appropriate cluster grouping. On this basis, it would be ideal to identify a readily available descriptive variable(s) which typifies a particular cluster's members.

Hooley and Saunders (40) have utilised database marketing for this end with great success. However, the possibility of applying this technique to the following work is limited. This is due to the amount of data that would need to be collected to construct the required database.

Approach for the Industrial Survey

The Euclidean distance measure has been chosen for the clustering procedure to be undertaken as part of the thesis, along with Ward's method of minimum variance for the combining of clusters. It would appear that these techniques are the accepted best practice by seasoned users of cluster analysis users. The aims and objectives of the work are discussed further in the following pages.

Marketing of DSM or Energy Services Programmes

The traditional approach to the marketing of DSM within the industrial sector has been characterised by the blanket offering of generic technologies and energy audits to all industry types. An alternative to this, whereby customers are targeted in accordance with the technologies or services which they are most likely to accept, and which fulfil there requirements, is introduced in the following paragraphs.

Traditional:

Utility DSM activity within the UK, and indeed that of Energy Services, has been very limited. The first DSM scheme in the UK, that carried out by Manweb on Holyhead, utilised a blanket approach in the targeting of industrial participants (18, 83). This was primarily due to the fact that Holyhead had very few industrial sites. However, despite this Manweb did manage to attract a 40 per cent participation rate by industrial sites through the DSM program. In order to make contact with these customers, Manweb utilised its billing database, mailing details of the proposed DSM program to every industrial site. Each industrial customer was offered a free energy audit and financial assistance where identified energy efficiency measures corresponded with utility load shaping objectives. Despite the offer of a free energy audit, nearly 40% of the target audience did not participate in the DSM program. Details on the number of sites that received an energy audit and progressed to installed subsidised measures are unavailable, as is information on how targeted the installed measures where in relation to the load shaping objective.

This approach to targeting industrial customers for DSM is sub-optimal in terms of program costs. The approach would appear to be flawed, particularly if applied to an area with many industrial customers, on the basis that the utility is reliant upon all industrial customers within a particular geographical area reacting in the same manner to DSM programs. The same would apply if Energy Services were offered with the underlying objective of optimising load curve.

Alternative:

An alternative to the traditional approach, whereby the differences between companies within the same geographical area can addressed, is possible through the analysis of company strategy, structure, and energy policy, and their relationship with energy efficiency. The analysis will reveal how any particular company views the concept of energy services or DSM in relation to its operational environment. As such it is likely that a different pattern of market segmentation to that suggested by SIC code for the provision of DSM programs, via energy services, will arise.

There are two methods of highlighting the differences suggested by this approach:

1. **Applying the technique within a particular SIC grouping:**

In order to take this approach it may be necessary to select an SIC grouping with a high number of companies within it. This would be required as a pessimistic response rate of 10% for the questionnaire, based on the requirement for 30+ replies in order to produce valid results, would imply that an SIC grouping of 300+ companies would be required. This appears unfeasible although it would highlight the failing of SIC groupings to account for the differences between companies in the area of energy efficiency.

2. **Applying the technique to all companies from a range of SIC groupings:**

   This approach would still draw out the differences between companies with regards to energy efficiency in relation to their strategy, structure, and energy policy. It would also highlight differences between companies within the same SIC although not to the extent that the study of a single SIC grouping would provide. However, it is believed that this approach is the most appropriate to use when considering the response rate to the questionnaire.

Segmentation Questionnaire

The questionnaire has been designed to provide information to allow an assessment of the varying attitudes towards investment in energy efficiency that exist within the industrial sector. This will ultimately enable the RECs to devise the most suitable energy services package for a particular customer, helping to reduce energy costs and possibly deliver improvements in productivity and quality. The following categories, or variables, within the questionnaire were selected through prior hypotheses and knowledge of the sector. The reader is directed to reference (132) in particular. The questionnaire was marketed to ten percent of the target audience. However, the author notes that with hindsight further development of the wording of the questions within the questionnaire may be required to prevent recipients from responding with an element of bias.

Company strategy & its importance & relevance to segmentation and EE

Company strategy covers the long term objectives of the company within its operating environment. Not all elements of company strategy are impacted upon by the concept of energy efficiency and energy services. However, those responsible for developing company strategy i.e. at director level, will consider any investment or policy shift in relation to company strategy. The issues of strategy that an investment in energy efficiency or energy services might affect are:

1. **Product Innovation** - a company that places a high level of priority on product innovation is likely to reflect this attitude in decisions on investment and policy. Innovative companies are characterised by a flexible and open culture that encourages new concepts and ideas. This culture is often seen to extend to areas outside core R&D and into cost reduction etc. (144).

2. **Invest in the Latest Production Technologies** - companies that consider having the latest production plant as essential to their competitive position are used to assessing novel technologies and techniques. As such they may be more likely to be more open-minded about the potential benefits of energy efficient technologies.

3. **Product Quality** - Many energy efficient technologies bring added benefits in terms of product quality. Companies competing on the basis of product quality would therefore be more likely to accept those energy efficient technologies and services that help to achieve this objective. However, those energy efficient technologies that provide cost savings alone, such as HEMs, may find little favour within these companies.

4. **Product Price** - Those companies that compete on the basis of product price often rely heavily on controlling and reducing costs in order to maintain their competitive status. Any proposal to reduce energy costs will be received with an enthusiasm which reflects the importance of competing on a product price basis.

5. **Risk Acceptance** - Different companies are seen to have different outlooks in terms of what they consider to be 'risk' . Innovative companies, for example, tend to be more willing to take higher risks due to the nature of their strategy of researching and developing new products (144).

6. **Public Image** - some companies strive to promote themselves to the public as 'good citizens'. The adoption of energy efficiency measures promotes a caring image of the company concerned, endearing to the company customers who feel empathy for emotive issues such as environmental protection. Many companies now make a commitment to environmental awareness in policy documents.

All companies will have elements of the above within their strategic outlooks. For example, all companies will compete on product price to a certain degree. However, it is the extent to which companies attach importance to any one of these issues that makes them slightly different.

Company Structure and Operating Procedures

These issues relate to the operations of directors and the structure of the company during day to day functioning of the business.

1. **Management Style & Cost Control** - The level at which cost control decisions are made can dictate the success of investment decisions and therefore any investment in energy efficiency (144.b). If decisions are made at managerial level then it is more likely that the promotion will be a success. This is a result of the manager having a greater focus on the application of the energy efficient technology and a more immediate realisation of its potential. Cost control investment that is subject to central approval can result in the benefits of a technology not being fully realised or understood. As such, the response to this question can enable electricity companies to identify appropriate marketing channels.

2. **Purchasing Policy** - Leasing of production plant technologies and site services represents a new business opportunity for utilities wishing to sell energy services or long-term contracts. The extent to which a company is prepared to accept the leasing of production and site services could reflect there propensity to participate in the energy services concept.

3. **Financial Assessment Criteria** - Companies vary in the techniques used to financially assess projects. The adoption of payback criteria for cost control measures is flawed and often restricts the adoption of energy efficiency measures (132). Net Present Value techniques would provide for the adoption of many more energy efficiency measures as it looks at the value of savings obtainable from an investment in energy efficiency over the life of the measure. NPV techniques for assessing the economic viability of energy efficiency are also more desirable as often the investment is relatively low risk.

Energy Policy

The concept of energy policy considers the objectives of the company with regards to energy consumption and utilisation. Issues impacted upon by energy policy which companies vary in attitude towards include:

1. **Control of energy**
2. **Monitoring of energy consumption**
3. **Maximisation of efficiency of existing production plant**
4. **Maximisation of efficiency of existing site services plant**
5. **Enhanced working conditions**
6. **Knowledge of latest production equipment and techniques**
7. **Nature of relationship with energy supplier**

The more positively a company views the above energy related concepts then the more likely they are to accept energy efficient technologies and energy services.

An example of the questionnaire utilised for this study is provided in Appendix C.

Results of Applying Cluster Analysis to Questionnaire Responses

Questionnaires were sent out to eighty ceramics companies across the UK. The companies were identified using the FAME database, a comprehensive database holding details of all UK registered companies. Selection was made from a range of ceramics subsectors, namely:

- **Tableware**
- **Tiles**
- **Hotelware**
- **Sanitaryware**
- **Industrial Ceramics**
- **Electrical**

Companies from the above sectors were selected at random. The ceramics sector was selected in order to ascertain the diversity of responses available from within a particular primary SIC grouping. The results of cluster analysis on the ceramics sector are analysed in the following pages. The response rate to the questionnaire was forty per cent, comparatively high when compared with the expected twenty per cent rate suggested in relevant literature (40).

Cluster Identification and Selection

Utilising 'Ward's' cluster procedure and the 'Euclidean Squared' distance measure, the agglomeration schedule revealed that an eight cluster solution was most appropriate. The full results are shown in Appendix A. The agglomeration schedule from this appendix is shown in Table 11.2.

	Clusters Combined			Stage Cluster 1st Appears		Next Stage
Stage	Cluster 1	Cluster 2	Coefficient	Cluster 1	Cluster 2	
1	21	23	7.5	0	0	3
2	3	8	16.0	0	0	4
3	13	21	29.2	0	1	17
4	3	15	44.0	2	0	14
5	18	22	60.0	0	0	20
6	4	20	76.0	0	0	11
7	12	16	92.0	0	0	9
8	9	14	108.5	0	0	13
9	1	12	127.2	0	7	15

	Clusters Combined			Stage Cluster 1st Appears		Next Stage
10	5	25	146.2	0	0	17
11	4	6	166.2	6	0	12
12	4	7	189.9	11	0	16
13	2	9	214.1	0	8	18
14	3	10	239.0	4	0	15
15	1	3	268.6	9	14	19
16	4	17	300.9	12	0	21
17	5	13	336.9	10	3	20
18	2	11	386.4	13	0	22
19	1	24	436.4	15	0	21
20	5	18	488.5	17	5	23
21	1	4	554.3	19	16	23
22	2	19	630.0	18	0	24
23	1	5	708.8	21	20	24
24	1	2	843.6	23	22	0

Table 11.2 : Agglomeration Schedule of Clustering Procedure, all Ceramics Respondents Utilised.

With all variables utilised the agglomeration schedule dictates that the optimum number of cluster solutions, i.e. the point at which there is a significant increase in the coefficient due to the joining of two clusters, is eight. The significance of this is discussed in the following pages.

Results of Cluster Analysis

The application of cluster analysis to the ceramics sector has resulted in the creation of eight clusters of ceramics companies. Each of the clusters contains a group of ceramics companies which have provided similar responses to the questionnaire on issues of company strategy and energy policy. Figure 11.5 provides details on the percentage of ceramics companies within each cluster grouping.

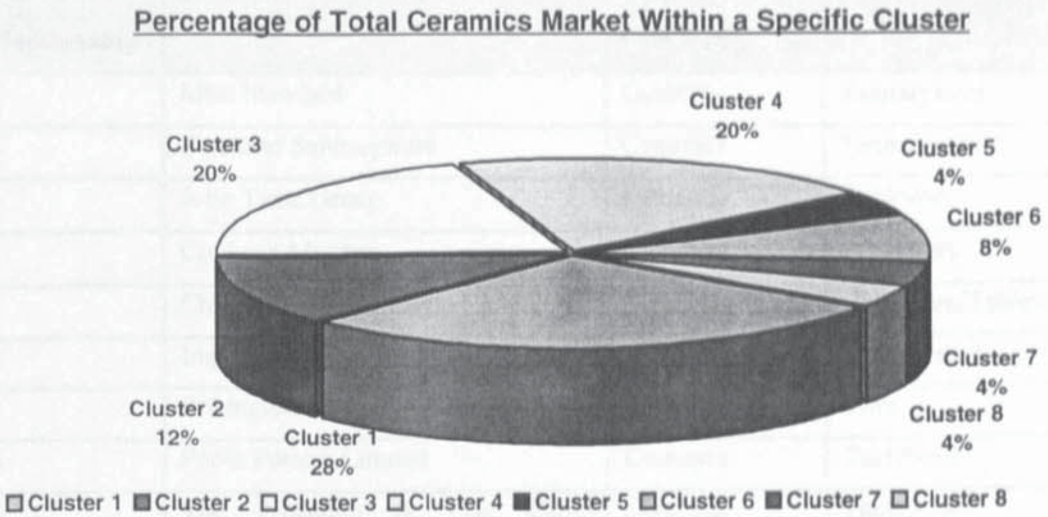

Figure 11.5 : Percentage of Ceramics Companies within each Cluster

The company groupings produced by the cluster analysis have been cross referenced with the levels of investment in energy efficiency, direct and in-direct, and the type of investment. The investment relates to a five year period prior to the completion of the questionnaire by the respondent. The process has revealed collective levels of investment, of various types, by the members of each cluster. The results show differing tendencies by the members of each cluster to invest in the various areas of energy efficiency. Table 11.3 details the results.

	Basic Maintenance	Plant Modifications	Organisational Changes	Improved Technology	Monitoring & Targeting	Price Sensitivity
Cluster 1	100	70	28	70	40	3.5 %
Cluster 2	100	66	33	66	66	5 %
Cluster 3	100	100	66	100	88	3 %
Cluster 4	100	100	40	100	80	4 %
Cluster 5	100	0	0	100	0	3 %
Cluster 6	0	0	0	100	0	8 %
Cluster 7	0	0	0	0	0	8 %
Cluster 8	100	100	0	100	0	8 %

Table 11.3 : Investment in Various Areas of Energy Efficiency by Cluster Groupings.

The Companies contained within each cluster are provided in Table 11.4. The cluster groupings are seen to contain a range ceramic manufacturing companies, manufacturing a diverse range of products. The cluster groupings produced by the cluster analysis are starkly different to those which would have been achieved had end-use manufactured product (SIC code) been utilised.

Cluster Membership	Company Name	Primary SIC Code (Type)	Secondary SIC Code (Type)
1	Ideal Standard	Ceramics	Sanitaryware
1	Barrhead Sanitaryware	Ceramics	Sanitaryware
1	John Tams Group	Ceramics	Tableware
1	Cookson Matthey	Ceramics	Refractory
1	Churchill Hotelware	Ceramics	Hotelware/Tableware
1	Imperial Bathrooms	Ceramics	Sanitaryware
1	Pilkington	Ceramics	Tiles
2	Poole Pottery Limited	Ceramics	Tableware
2	The Procelain & Fine China Companies	Ceramics	Tableware
2	Unitec Ceramics	Ceramics	Technical Ceramics
3	H&R Johnson	Ceramics	Tiles
3	James Sadler & Sons	Ceramics	Tableware
3	Steelite International	Ceramics	Hotelware/Tableware
3	Ross Catherall Ceramics	Ceramics	Other Ceramics
3	Portmerion	Ceramics	Tableware
4	Furlong Mills Company	Ceramics	Tableware
4	MH Detrick Company	Ceramics	Bricks/Tiles/Construction
4	A.Wood & Sons	Ceramics	Tableware
4	Wade Ceramics	Ceramics	Refractory/Tableware
4	Caradon Bathrooms	Ceramics	Sanitaryware
5	Morgan Matroc	Ceramics	Industrial Ceramics
6	Staffordshire Tableware	Ceramics	Tableware
6	Jesse Shirley & Sons	Ceramics	Tiles
7	CBL Ceramics	Ceramics	Sanitaryware
8	Universal Abrasives	Ceramics	Other Ceramics

Table 11.4 : Cluster Membership of Respondents in Accordance with Industrial Sector.

A brief description of the cluster groups, detailing the underlying nature of the companies contained within them towards energy and business related issues is provided in Table 11.5.

Cluster	Business Objectives	Business Operations	Energy Policy	Price Sensitivity
No. 1	Primary focus on manufacturing high quality goods within a highly competitive market. Typically, these companies face strong competition from foreign manufacturers & respond by differentiating on quality.	High awareness of cost control, with related investment decisions carried out at board level. Slight scope for low/mid management persuasion.	Seek a close two-way relationship with energy supplier. Will often look to supplier for information and assistance on energy related issues. Moderately pro-active maintenance of both production plant and site services, although not optimised.	Very price sensitive. An annual increase in energy rates of 3.5 % is deemed to promote energy efficiency.
No. 2	Typically brand-led companies manufacturing reputable, superior quality products. These companies try to avoid price based competition.	Investment in cost reduction at board level utilising relatively sophisticated accounting techniques. Low investment in latest technologies, reflected in their comparatively high aversion to risk.	These companies believe that they have a suitably high level of control over energy costs. Investment in energy efficient technology is relatively high. However, maintenance of both site services and production plant is low, with an equally low value placed on their ownership.	A 5% annual increase in energy rates would prompt active investment in energy efficiency.
No. 3	These companies are characterised by the manufacture of high quality, keenly priced, goods within an extremely competitive market. These companies are forward thinking and ready to adopt innovative technologies in order to maintain growth.	Typically very high levels of investment in the latest production technology in order to obtain a competitive advantage, reflecting their high acceptance of risk. Cost control investment is relatively autonomous at a departmental manager level.	These companies closely monitor and target energy consumption and costs. They seek to maximise the efficiency and reliability of equipment, with energy saving investment is viewed as being of very low risk. These companies are extremely keen to develop involved relationships with energy suppliers.	Extremely price sensitive. An annual increase in rate of 3 % is enough to promote active investment in energy efficiency.

Cluster	Business Objectives	Business Operations	Energy Policy	Price Sensitivity
No. 4	Typically involved in mass manufacture, these Companies compete primarily on product price. These companies do, however, show relatively high levels of product innovation.	Similar to Cluster 3. However, Companies within this cluster are slightly aversive of risk, yet utilise very sophisticated financial appraisal techniques.	Energy saving investment viewed as low risk. Maintenance of site services and production plant is pro-active, with ownership of both viewed as being important. Confident of energy control yet realistic of scope for improvement.	Moderately cost sensitive, annual increase in energy rate of 4% promotes investment in energy efficiency.
No. 5	Companies mass manufacturing standard products with little innovation.	Invest heavily in the latest production technology and are acceptant of risk. Cost control investment is highly localised at departmental manager level, and determined by simple appraisal techniques.	These companies are characterised by low levels of maintenance of site services and production plant. Ownership of both is seen as non-essential. These companies are characterised by low levels of investment in energy efficiency despite being aware of their being highly inefficient.	Highly cost sensitive. 3% annual increase in energy rate would prompt investment in energy efficiency.
No. 6	These companies are typically marketing products at the mid-higher range of the market, with established brand names. Concern for product quality often overrides that for cost control.	Characterised by relatively moderate investment in new technology, these companies are highly risk aversive. Retention of ownership of site services and production plant is seen as fundamental. All investment is strictly controlled at board level.	These companies are conscious that they do not optimise energy efficiency, yet are fully aware of how to improve.	An energy rate increase as high as 8% per year would be required to stimulate energy efficiency investment.

Cluster	Business Objectives	Business Operations	Energy Policy	Price Sensitivity
No. 7	Forward thinking companies, investing heavily in the latest production technologies and highly acceptant of risk. Focusing upon producing innovative products of superior quality, avoiding price based competition.	These companies are focused upon producing innovative products. Highly acceptant of risk, they are prepared to be the first to utilise latest production techniques. Companies within this cluster tend to avoid ownership of production plant and site services.	Totally devoid of any desire to manage energy. These companies acknowledge energy saving investment as low risk but have no desire to invest. They desire minimum contact with energy suppliers.	Highly insensitive to energy rates. Annual increases in rates in excess of 8% would be required to promote energy efficiency investment.
No. 8	Competing in highly competitive markets on both product quality and product price. These companies fully utilise, and continue to develop, a strong brand name as a central part of their business strategy.	These companies attach a high level of autonomy to local managers in respect of cost control investment. Payback is the overriding appraisal method.	Highly pro-active maintenance on production plant and site services. Confident of their ability to control energy usage although they believe that energy efficiency investment is no less risky than investment in other areas.	An energy rate increase as high as 8% per year would be required to stimulate energy efficiency investment.

Table 11.5: Description of Cluster Groupings

Table 11.5 highlights the differences that exist between ceramics companies in their approach to energy efficiency, business objectives, and business strategy, as revealed by the cluster analysis. However, these descriptions of the various cluster groupings are general in their approach and are primarily useful only to provide an overview of the potential market segments. The results of the cluster analysis require more detailed analysis if the derived segmentation's were to be utilised commercially.

The differences between cluster groupings are reflected through the comparative extent of investment in energy efficiency. Cluster 3, for example, is seen to invest in many aspects of energy efficiency and has a sophisticated approach to energy management. This is related to the market in which these businesses find themselves, a market which is extremely competitive and demands extremely tight control over costs. Additionally, these companies also attach a high value to a close relationship with their energy supplier in order to obtain advice and assistance in controlling energy cost and consumption.

At the other end of the spectrum, Cluster 7 consists of companies which have made no investment in energy efficiency, directly or indirectly, over the past ten years. These companies focus upon the delivery of a high quality product, avoiding price competition. This premium quality commands a premium price and, as such, dictates that energy costs and cost control are not of prime importance. These companies are aware that they have a poor level of control over energy costs, and that energy efficiency is low risk, but invest minimal amounts of capital into energy efficiency. Additionally, these companies have no interest in developing a relationship with their energy supplier.

In terms of a DSM or Energy Services programme, companies within Cluster 7 would represent a conundrum. This is true due to the fact that they would represent an opportunity for highly cost effective load reduction etc. yet would not be interested in participating in the programme. However, Cluster 3 companies represent a different proposition. These companies are very keen on energy efficiency and would readily become involved in DSM or Energy Services. However, within these companies a REC may find very few opportunities for load reduction etc., thus potentially driving up the cost of any programme.

Due to the lack of DSM initiatives within the UK it is difficult to identify, with a high degree of certainty, which companies are more inclined to opt for one particular energy efficiency measures over another. For the same reason, there is a lack of data available concerning the effects on market penetration rates or technology acceptance in response to tailored DSM or Energy Service offerings. On this basis, the only option was to inquire as to which areas of energy efficiency companies had invested in over the past ten years. This method allows an insight into the types of DSM or Energy Service offerings that could be attractive to the respondent companies. On the basis of this information tentative suggestions can be made as to which energy efficiency technologies are likely to be present at a company within a particular cluster. It may also be possible to predict those technologies or service offerings which would be more likely to gain a positive response when proposed to the targeted cluster.

The exact number and specific types of measure applicable to each respondent company was not ascertained in some cases. This was often a consequence of the questionnaire being addressed at technical director level. On several occasions the respondents had not been at the company for long enough in order to recollect investment on cost cutting over the past ten years.

Table 10.6 provides information on the measures adopted by companies within a particular cluster. The percentage of companies within a cluster which have actually invested in the applicable area is shown in brackets.

	APPLICABLE DSM/ENERGY SERVICE MEASURE				
Cluster	Insulation, Zonal Steam Control, Lagging.	HEM's, HEL's, Pfc, Heat Recovery.	Energy Manager, Process Rescheduling, Modified Shifts.	Improved/Innovative Technologies	Monitoring and Targeting
1 (28%)	✓ (100%)	✓ (70%)	✓ (28%)	✓ (70%)	✓ (40%)
2 (12%)	✓ (100%)	✓ (66%)	✓ (33%)	✓ (66%)	✓ (66%)
3 (20%)	✓ (100%)	✓ (100%)	✓ (66%)	✓ (100%)	✓ (80%)
4 (20%)	✓ (100%)	✓ (100%)	✓ (40%)	✓ (100%)	✓ (80%)
5 (4%)	✓ (100%)	× (0%)	× (0%)	✓ (100%)	× (0%)
6 (8%)	× (0%)	× (0%)	× (0%)	✓ (100%)	× (0%)
7 (4%)	× (0%)	× (0%)	× (0%)	× (0%)	× (0%)
8 (4%)	✓ (100%)	✓ (100%)	× (0%)	✓ (100%)	× (0%)

Table 11.6 : Energy Efficiency Measures/Technologies Adopted by Cluster Classification

The information in Table 11.6 can be utilised in order to provide an indication of the likely participation of various companies in a particular DSM initiative. On this basis, electricity companies will be able to optimise DSM programme participation rates through addressing the specific needs of the customer segments.

Further to the above, the information provides an opportunity to address any 'profitable sleepers' i.e. those companies who do not invest, or make minimal investment, in a particular area of energy efficiency. The reasons for this lack of investment, such as a lack of information or awareness of relevant technologies, can then be addressed by the electricity supplier. Such companies could prove to be highly effective in DSM programmes. This is due to the fact that they are often able to reduce consumption and demand by significant amounts and at a low cost. In the same respect, these companies could be highly attractive to electricity companies offering energy services or long term supply contracts.

Table 11.7 details the likely participation rates in DSM or energy service offerings when considering past investment by respondent companies in energy efficiency technologies.

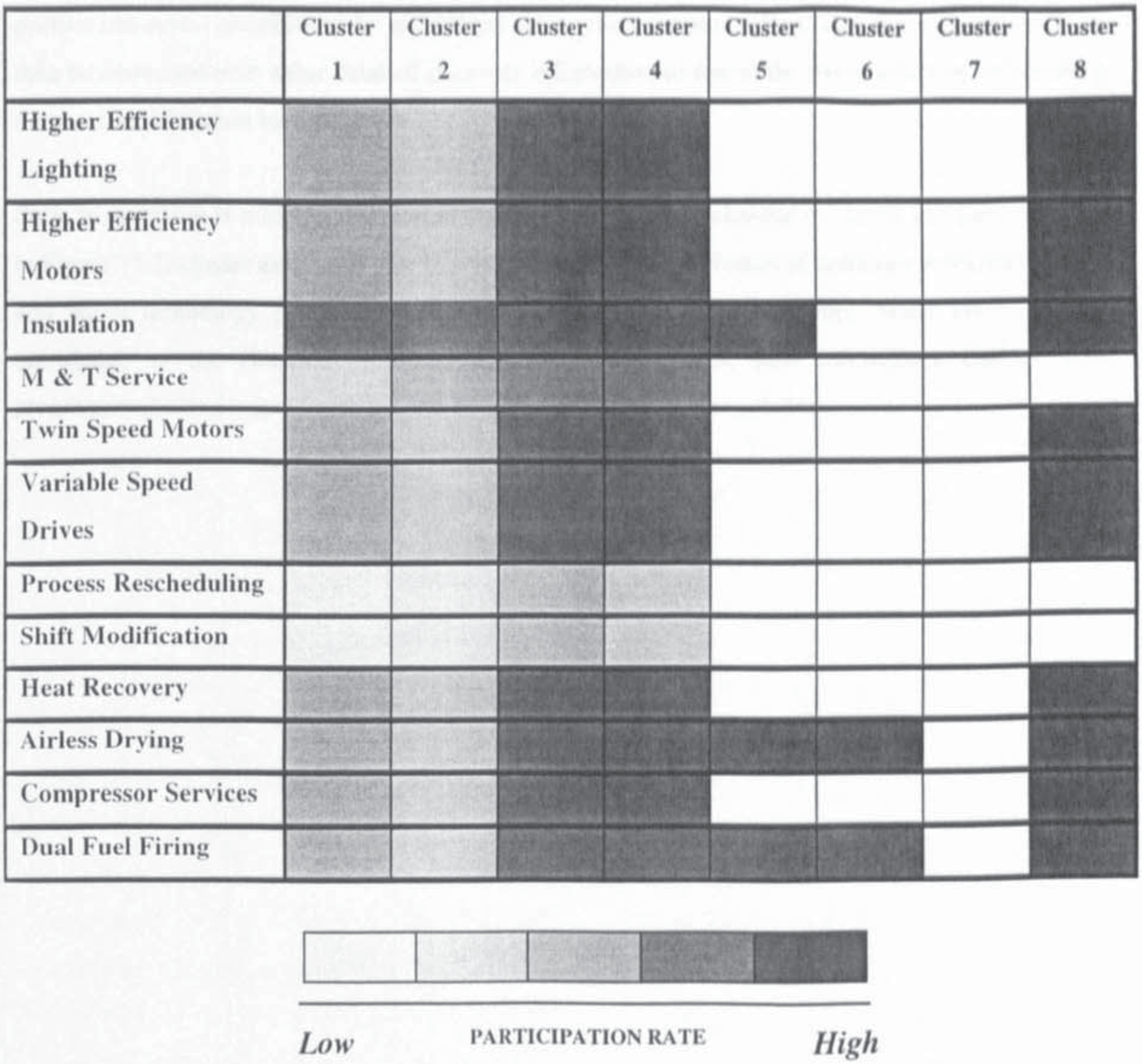

Table 11.7 : Projected Participation Propensity DSM Measures

Potential participation levels can be further refined through the analysis of other primary needs. For example, companies within clusters 3, 5, and 8 all assign a high value to investment in the latest production technologies and are acceptant of investment risk. These companies have also invested in improved production technologies over the past five years. As such these companies should be targeted first during any DSM/Energy Services programme that seeks to promote an innovative production technology as a feature of a DSM/Energy Services programme.

This detailed information on customer energy needs, detailing previous investment in energy technologies and likely participation rates, can then be combined with other information to provide a comprehensive assessment of energy services and DSM potential within an industrial sector. This other information refers to that already obtained on processes and production technologies within the sanitaryware sector.

Detailed information at a process and end-use technology level can provide a valuable insight into the potential for various load shaping objectives within a particular industrial sector. The analysis of load profiles can reveal possibilities for technology substitution or optimisation. This energy information can then be combined with other detailed customer information to reveal the likely effect of DSM/Energy Services on substation load profiles.

Such an approach is made more practical through applying the technique of cluster analysis. As shown in Figure 11.7, cluster analysis is able to provide a first-order prediction of customer participation rates, and hence technology penetration levels, of a range of DSM programmes. When combined with knowledge of the electricity profiles of various technologies, such information enables DSM programmes to be designed with the aim of arriving at the least cost solution.

CHAPTER 12

DISCUSSION

PREDICTION OF ELECTRICITY DEMAND WITHIN THE SANITARYWARE SECTOR

Introduction

It is desirable to obtain an approximation of the cumulative installed capacity for the sanitaryware sector at a process level. This would greatly assist a non-intrusive preliminary assessment of energy services and DSM.

When considering the opportunity for DSM within a particular area of a distribution network an accurate knowledge of both the timing and magnitude of electrical demand, at high (primary transformer) and low (customer) order levels, is fundamental. Detailed information on a higher level of the network, such as transformer kVA loadings, are already available to RECs via SCADA systems.

However, information on a particular industrial sub-sector and its timings and magnitudes of electricity usage extends no further than total site billing. In order to carry out an effective DSM or energy services programme information on the sub-sector in question is required at a much more disaggregated level. Information on electricity utilisation at an end-use technology and process level will enable DSM planners to minimise costs and inconvenience to the end-user. It would further allow a more effective targeting of technology applications to provide DSM or energy services solutions.

This study attempts to predict the electrical demand associated with a particular process within a particular manufacturing site. Regression analysis, utilising site throughput and knowledge of end-use technology operating times and typical kW ratings, has been used as a simple tool with which to assist DSM planning and analysis. The author wishes to point out that the sample size used in the analysis is small, being ten in total. This may have some influence over the robustness of any regression line produced and as such results should be treated with caution. The feasibility, and accuracy, of making forecasts of electrical demand profiles at a particular site is explored in the following pages.

Predicting Cumulative kW Demand by Process Area

The manufacture of sanitaryware is characterised by clearly identifiable process stages common to all throughput. Sanitaryware manufacturers, for historical and practical reasons, are seen to employ common manufacturing techniques across these process stages. Materials preparation, drying, and firing represent such process stages, with each manufacturing site in the UK utilising common end-use techniques and technologies.

Materials Preparation

Through the application of regression analysis it has been possible to produce a strong correlation between site production throughput and cumulative electrical capacity for the materials preparation process, as shown in Figure 12.1.

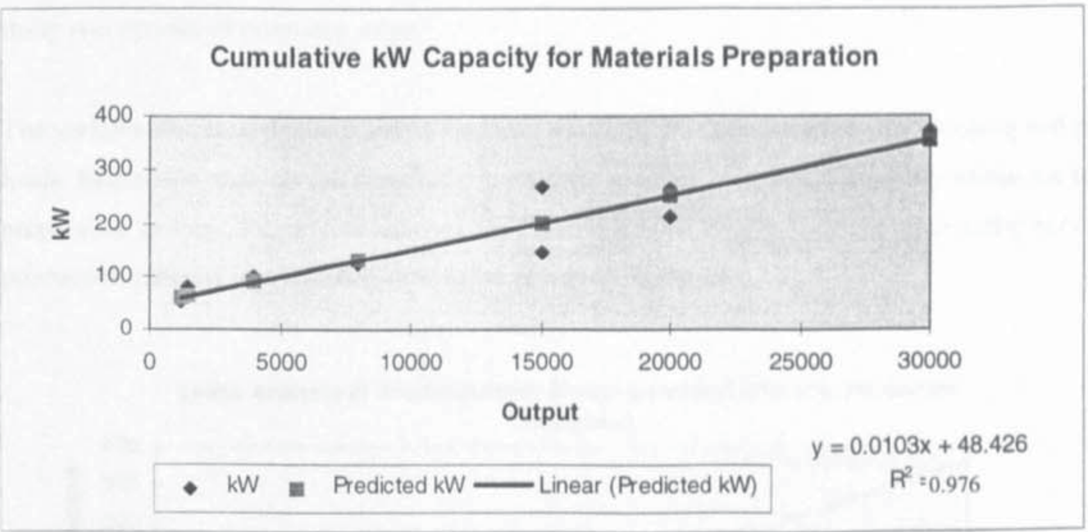

Figure 12.1 : Regression analysis of Cumulative Material Preparation Capacity (kW).

The linear regression analysis utilised to construct Figure 12.1 returns a significance value (*R Square*) of 0.91. The F-Critical value of 87.4, F-Critical value needing to exceed 4.53 for significance, indicates that the relationship defined in the equation is useful in predicting cumulative kW capacity for materials preparation on sites within the sanitaryware sector. It is considered that the relationship between installed capacity and site throughput provides a degree of accuracy which is high enough to minimise the usefulness of identifying further variables to utilise within a multiple regression analysis.

Having identified the installed cumulative electrical demand for the materials preparation process it is desirable to attribute the relevant proportions of this demand to actual time periods and end-use technologies over the production day. This has been attempted through the monitoring and analysis of end-use technology operations. The monitoring and analysis has revealed that materials preparation has a base load demand attributable to constant operation of certain end-use technologies, namely agitators and storage-tank mixing paddles. The variable demand attributable to materials preparation has been identified as that attributable to the end-use technologies of pumping and blunging.

Assigning Process Capacity to End-Use Technology Utilisation

Base load operation within materials preparation is defined as those technologies which are operating for twenty four hours per day. As such, these technologies are identified from Table 9.2 of Chapter 9 as being agitators, storage arcs, and storage tanks. An analysis of the sanitaryware sites studied has revealed that, on average, the base load accounts for thirty two percent of the total cumulative capacity of the materials preparation process over each time period. This mean value returned a standard deviation of 8.9. On this basis it is possible to utilise the value of cumulative kW demand obtained through linear regression in order to ascertain base loading for the materials preparation process i.e. thirty two percent of estimated value.

The variable electrical demand within materials preparation is attributable to the blunging and pumping loads. Regression analysis can be utilised to estimate installed blunger kW capacity within the materials preparation process. Regression analysis has established that there is a strong relationship between site production capacity and installed cumulative blunger kW capacity.

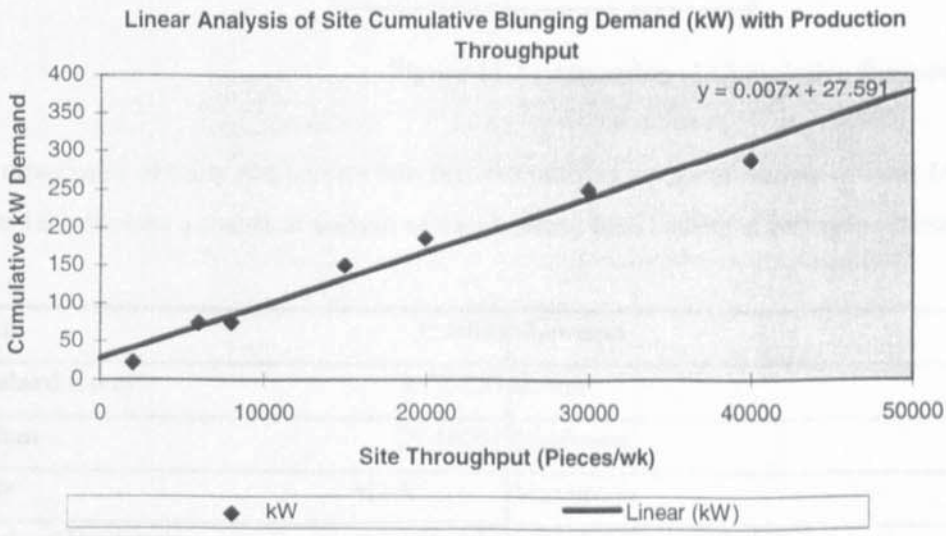

Figure 12.2 : Regression analysis of kW Blunger Capacity

The linear regression analysis utilised to construct Figure 12.2 returns a significance value (*R Square*) of 0.97. The F-Critical value of 179.67, F-Critical value being 4.53, indicates that the relationship defined in the equation is useful in predicting cumulative kW blunging load for sites within the sanitaryware sector. This relationship is, to a large degree, to be expected due to changes in plant sizing designs.

Timing of Electrical Demand

The thirty two percent of cumulative capacity assigned to base loading , representative of slip tank 24 hour operation, can simply be distributed to a flat twenty four hour profile, as shown in Figure 11.3.

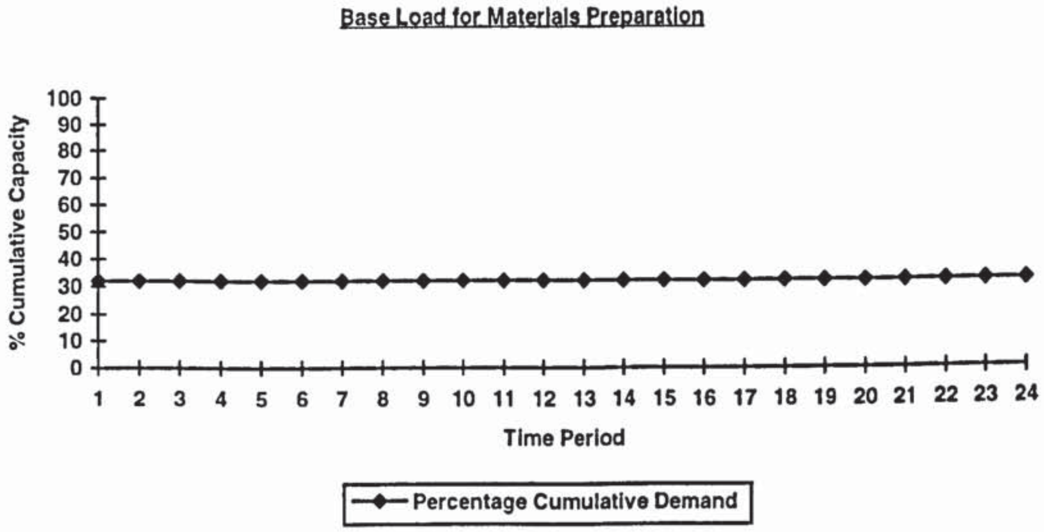

Figure 12.3 : Allocation of Cumulative Demand to Base Load

The mean value of thirty two percent falls between outlying values of twenty two and forty six percent. Table 12.1 displays a statistical analysis of the identified base loading at surveyed sanitaryware sites.

Mean	32.0706	Skewness	0.489364
Standard Error	3.175295	Range	23.55102
Median	29.16667	Minimum	22
Mode	#N/A	Maximum	46
Standard Deviation	10.04116	Sum	320.706
Sample Variance	100.825	Count	10
Kurtosis	-1.7111	Confidence Level (95.000%)	6.223454

Table 12.1 : Statistical Analysis of Base Loading Within Materials Preparation

This information can then be placed in the context of a typical blunging cycle shown in Figure 12.4. The blunging cycle will typically last for between two and two and a half hours, following the demand profile shown. Three blungers have been logged electronically. Blungers at other sites, 12 in total, have been logged in terms of operating periods, control type, and equipment type. A real-time logged profile of demand of a blunger during a full cycle is available in Appendix A.

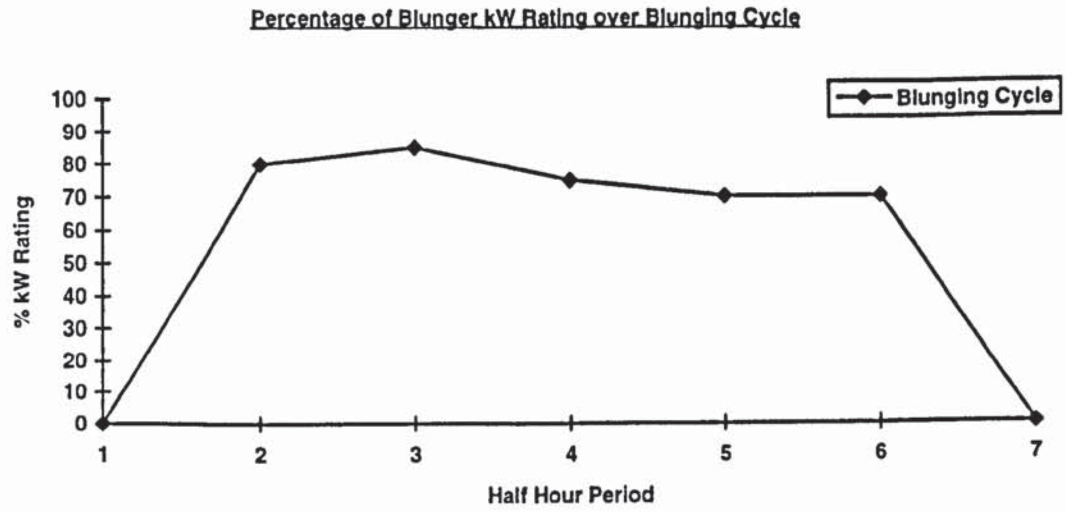

Figure 12.4 : Blunging Cycle Demand Profile

However, the problem remains as to the prediction of when the blunging cycle actually occurs. It would be difficult to predict the exact time of the blunging operation at any particular site. This is due to the operation occurring in relation to production demand/throughput and also to shift start and finish times at the site in question. Despite this, it is possible to provide an insight into the probable time periods in which the blunging operation will occur. Probability is defined as the percentage chance of the blunging operation occuring within the particular time period at any one site. Figure 12.5 provides this insight.

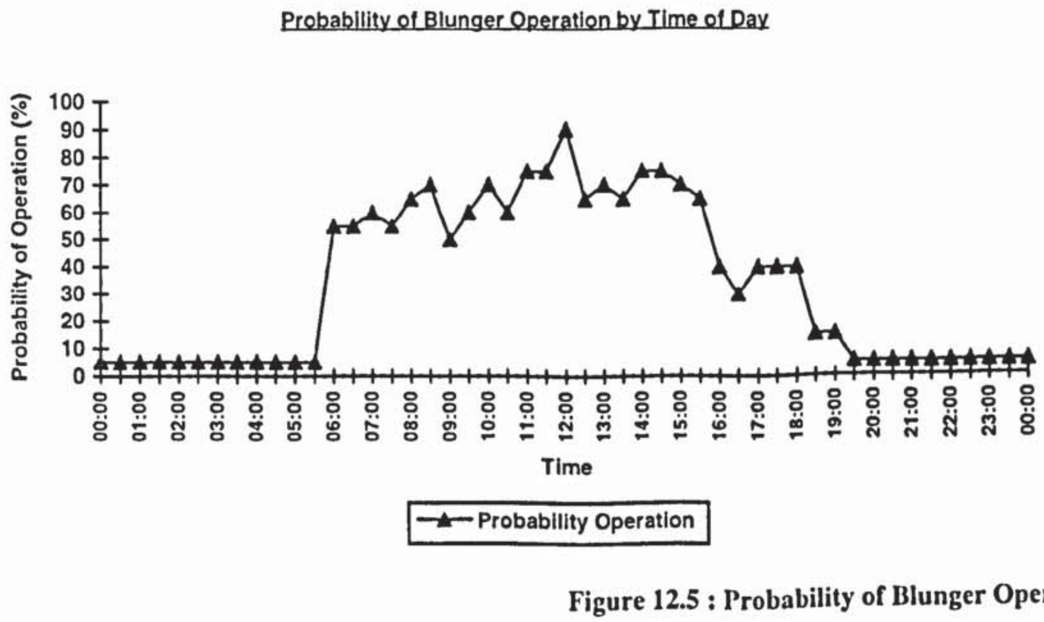

Figure 12.5 : Probability of Blunger Operation

Figure 12.5 provides an insight into the timing of the electrical (kW) demand associated with the blunging operation. It is evident that blunging operation is greatly limited to the hours between 06:00 and 18:00. In addition to this, it is evident that over 50% of all blungers on any one site will be operating during the hours between 06:00 and 15:00, with almost 90% being operational between 11:30 and 12:30.

It is practically impossible to predict the exact timing of electrical demand attributable to the variable operation of identified end-use technologies within the materials preparation process. In a case where many sanitaryware sites (or perhaps ceramics sites) are connected to a particular substation then it may be possible to utilise an averaged approach, or generic profile, as seen through the Demand Estimation Coefficients (DECs) utilised for cumulative domestic loads. These domestic DECs, as created by the Electricity Association, represent the cumulative loading of domestic customers on a transformer. As such, no individual domestic customer has a demand profile that matches a DEC, but the combined loading can be reconciled to demand on a transformer.

However, the information provided by Figures 12.1-12.5, when utilised in conjunction with Table 9.2, can provide a valuable preliminary insight into the probable magnitude and timing of electrical demand associated with the blunging operation. As such, any requirement from a local network DSM program in relation to the specific timings of electrical demand can be readily addressed.

For example, consider a local network transformer that is found to have a peak load which exceeds firm capacity at 12:00 hrs. From the information provided in the above, the most significant electrical load relating to this period on a sanitaryware site could be identified as that of induction motors related to the blunging operation.

Drying

The survey results revealed that all sanitaryware manufacturers in the UK practice the technique of shop drying. This technique (see Chapter 9) is dominated by gas consumption, with electricity representing 10 to 30 per cent of total energy consumed. The percentage value represented by electricity increases as system efficiency increases by virtue of reduced gas consumption.

Gas and electricity consumption, and hence demand, are not highly correlated within the shop drying process. Further, correlation between shop drying area (capacity) and electricity consumption is also relatively low. This reflects the fact that most shop drying systems have evolved over time without a substantial amount of planning or assessment, making the technique something of a 'black art'.

Gas consumption also shows only a slight correlation with shop dryer capacity. This is a reflection of the fact that the efficiency of a shop drying system is highly dependent upon the thermal insulation at the system boundaries. Hence, poor insulation and resultant higher heat loss requires oversizing of both burners and fan power in order to achieve the necessary temperatures and heat distribution around the ware. On this basis it would be necessary to derive an average SEC electricity and gas value for the range of shop drying efficiencies found in the survey.

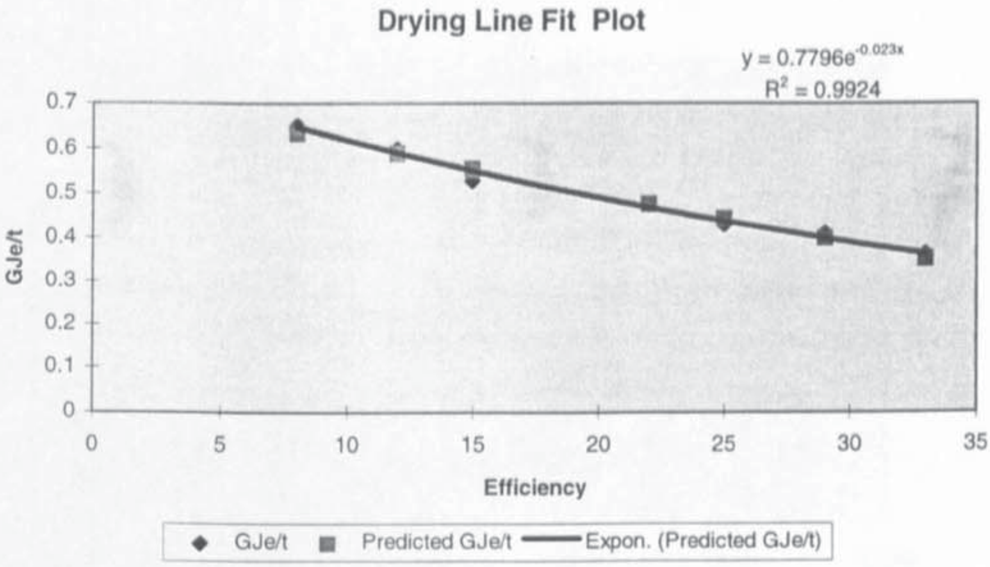

Figure 12.6 : Regression Analysis of Predicted kW Demand with Shop Dryer Efficiency.

The relative efficiencies derived from the line fit of Figure 12.6 are then assigned descriptive indicators of typical drying systems which correspond to the efficiency fit. For example, a low efficiency shop drying system corresponding to an efficiency of fifteen per cent or less would typically have minimal insulation at the system boundaries, leading to high rates of heat loss, and would be under utilised, operating at throughput levels of only one piece per ten cubic metres of drying area volume. Figure 12.6 displays the exponential relationship between drying SEC per tonne and drying system efficiency. Table 12.2 displays the high levels of confidence in the accuracy of the suggested relationship.

Regression Analysis	Values
Multiple R	0.98892
R Square	0.977963
Adjusted R Square	0.97429
Standard Error	0.015522

Table 12.2 : Regression Analysis of Shop Dryer Efficiencies.

Chamber dryers, unlike shop dryers, have been designed and engineered as dedicated dryers. In these dryers electrical load has a direct relationship with dryer volume. Conversation with dryer manufacturers has revealed that the design of chamber dyers, with respect to electrical loading, is carried out on the assumption that a doubling in dryer capacity would lead to an approximate increase in kW loading by a factor of 1.5 to 2.

A number of chamber dryers audited as part of the survey were analysed using linear regression. The results are shown in Figure 12.7.

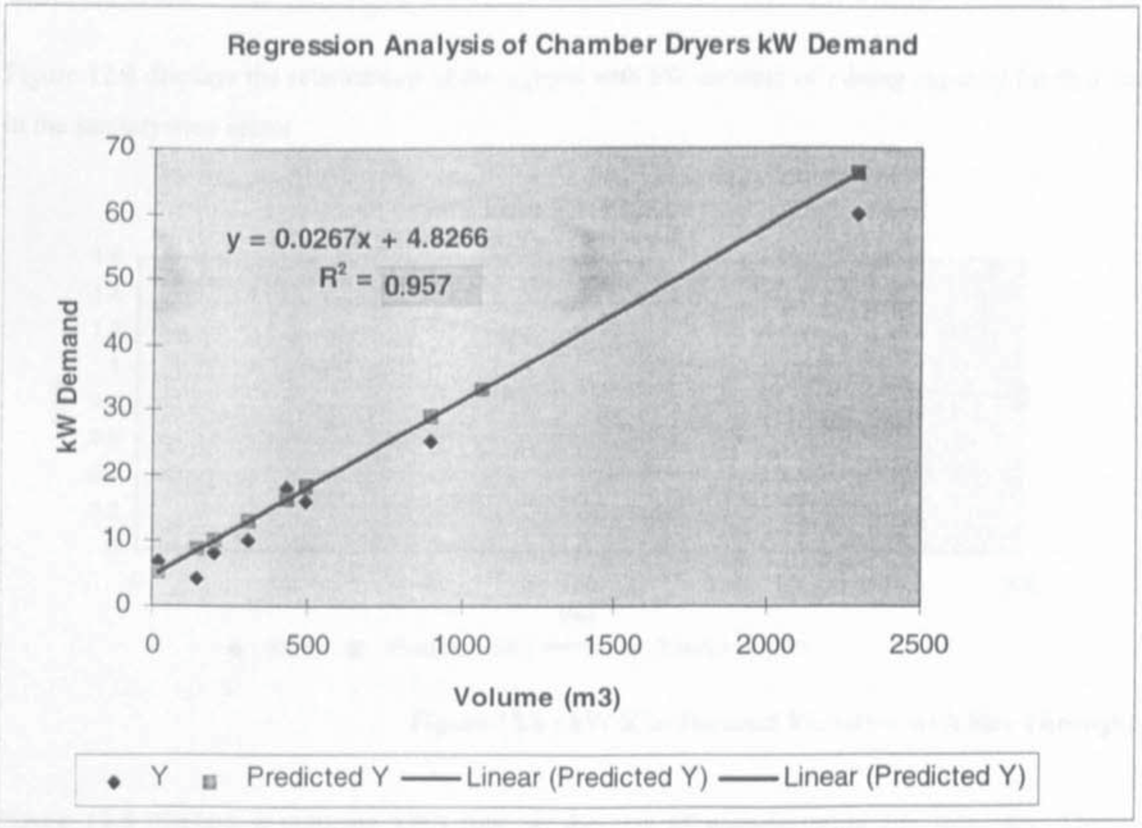

Figure 12.7 : Regression Analysis of Conventional Chamber Dryers.

There is a high correlation between Chamber dryer volume and kW electrical demand. However, there remains the difficulty of assigning this cumulative demand to individual devices within the dryer itself. Chapter 10 revealed information on these individual devices, such as recirculation, burner, and extract fans. Despite this, the wide variation in the numbers of devices for each application makes the further disaggregation of a cumulative kW demand to an end-use device level unpractical.

Figure 12.7 does not take into account the steam injection units found on the majority of chamber drying units. As a general rule steam injectors, or humidity control units, have a lower rating of 30 kW for capacities of below 1000 m^3, rising to 40 kW above this threshold. Steam injectors were left out of the analysis due to the tendency of most manufacturers to disconnect the units on the grounds of high running costs and minimal influence on product quality.

Firing

Figure 12.8 displays the relationship of throughput with kW demand of kilning capacity for first firing in the sanitaryware sector.

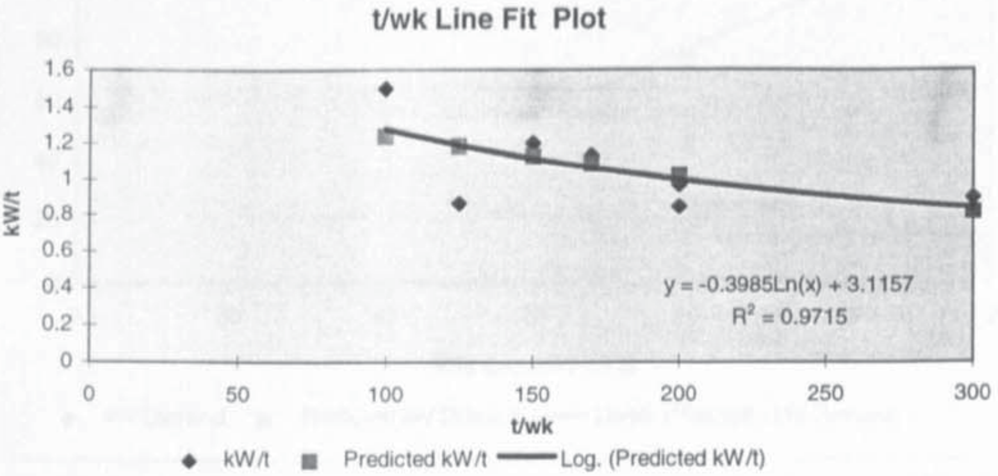

Figure 12.8 : kW Kiln Demand Variation with Site Throughput

Figure 12.8 displays a reducing kW/t ratio as the size of manufacturing site increases. This is a reflection of the fact that the larger sanitaryware manufacturers, typically producing in excess of five thousand pieces per week, operate tunnel kilns. These kilns, as described in Chapter 9, generally have a lower SEC value due to their high levels of utilisation. Smaller manufacturers producing less than approximately five thousand pieces per week have a proportionately higher amount of throughput fired in intermittent kilns and therefore have higher SEC values.

Although useful for showing an absolute trend of kW change with throughput levels, Figure 12.8 is unable to identify the number of kilns or type of kilns in operation at a particular site. As such, its use is limited in terms of assisting DSM.

A number of factors influence the kW demand rating of a tunnel kiln. These factors include age and type of kiln i.e. whether the kiln is of muffle or direct gas type, as well as the volumetric capacity of the kiln. Over ninety per cent of sanitaryware fired by tunnel kilns is fired through direct gas burner kilns, the remainder being fired by muffle kilns. These muffle kilns are generally very old brick structured kilns and rely upon natural draught to maintain kiln pressure and firing profile, rather than the multitude of fans installed in modern kilns. Modern direct gas fired kilns have a larger electrical load by virtue of a greater number of fans to assist the obtainment of the desired temperature profile and kiln pressure. Figure 12.9 displays the linear relationship between the cumulative kW demand rating of a modern direct gas fired single track tunnel kiln with kiln capacity.

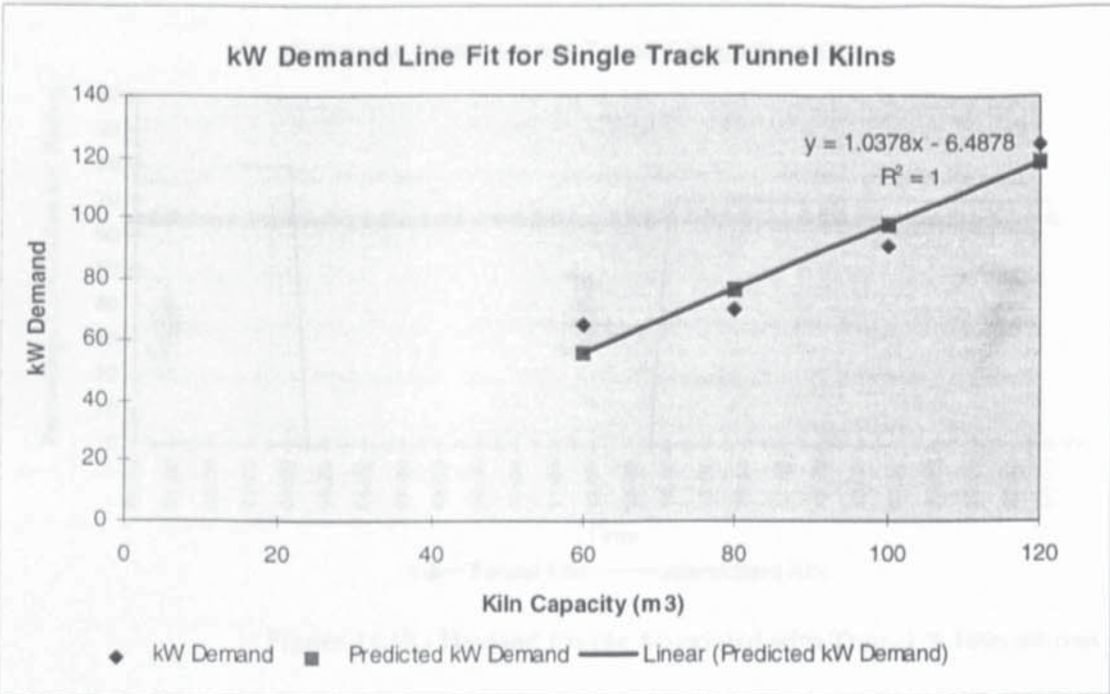

Figure 12.9 : Linear Regression Analysis of Tunnel Kiln kW Demand with Kiln Capacity.

The regression analysis provides a relatively accurate prediction of kW electrical demand on modern direct gas fired tunnel kilns. The Table below provides statistical indicators of significance and accuracy.

Regression Statistics	
Multiple R	0.951915
R Square	0.906143
Adjusted R Square	0.882678
Standard Error	8.731077

The allocation of the derived kW demand rating is relatively simple for tunnel kilns in the sanitaryware industry. Tunnel kilns have a constant kW demand, unrelated to throughput, operating over a twenty four hour period. Even with the application of variable speed drive on the exhaust fan of a tunnel kiln, electrical loading will vary to a minimal extent as exhaust fans typically represent a maximum of ten per cent of overall kiln electrical load. As such, allocation of kW demand across the kilning process is carried out across a flat twenty four hour profile, as shown in Figure 11.10. Real time kW demand profile obtained from the actual logging of a tunnel kiln can be found in Appendix A.

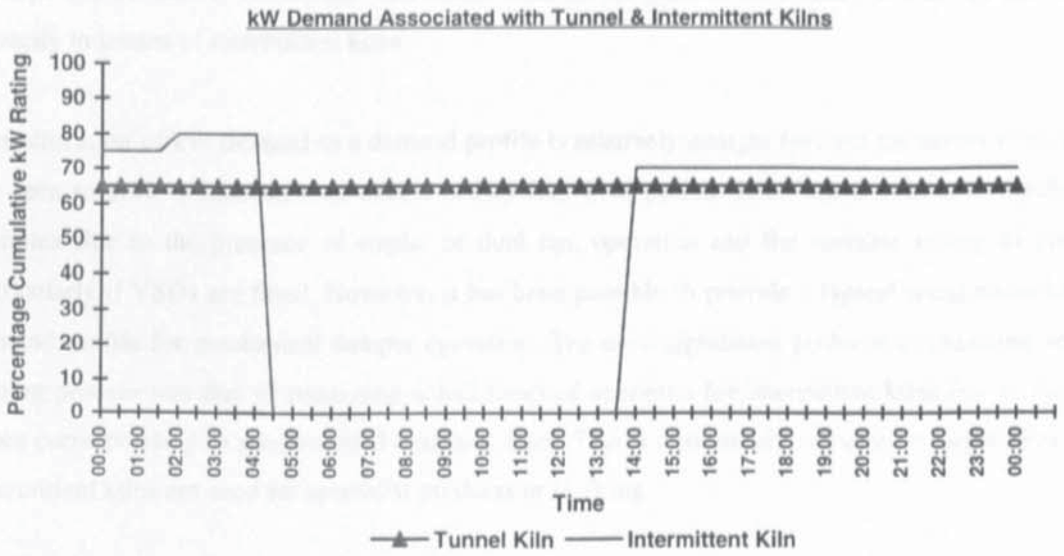

Figure 12.10 : Demand Profile Associated with Tunnel & Intermittent Kilns

Intermittent kiln demand profiles are cyclical. This corresponds to the nature of kiln operation. The demand profile increases towards the end of the firing cycle as dampers are opened to assist cooling of the kiln. A linear regression equation is used to determine kiln kW loading in relation to kiln throughput capacity. On this basis, information is required on the number of intermittent kilns on a particular site and the throughput capacity of each.

Intermittent kilns surveyed in the sanitaryware sector had capacities ranging from 125 to 1000 pieces per unit. The results provided a logarithmic regression line-fit between kiln capacity and kW electrical demand, as shown in figure 12.11.

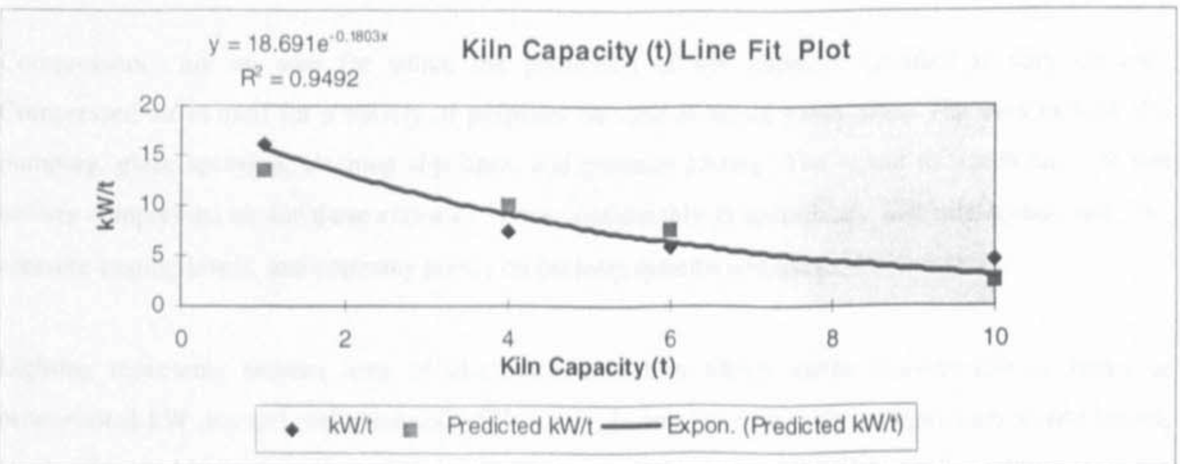

Figure 12.11 : Regression Analysis of Cumulative kW Demand of Intermittent Kilns

The information obtained form sanitaryware manufacturers regarding the kilns in which are operating to date has enabled the construction of regression models to predict the kW demand for tunnel and intermittent kilns. Having initially identified cumulative site kW demand for firing, it is possible to allocate this demand to intermittent and tunnel kilns on the basis of the number of kilns on site, and the capacity in tonnes of intermittent kilns.

The allocation of kW demand to a demand profile is relatively straight forward for tunnel kilns as they are seen to draw a constant load over a twenty four hour period. Intermittent kilns are slightly more complex due to the presence of single, or dual fan, operation and the variable setting of dampers, particularly if VSDs are fitted. However, it has been possible to provide a typical intermittent kiln kW demand profile for mechanical damper operation. The most significant problem encountered with the kilning process was that of predicting actual times of operation for intermittent kilns due to operating times corresponding to production throughput rates. This is particularly relevant on larger sites where intermittent kilns are used for specialist products or re-firing.

Other Process Areas and Site Services

Electricity utilisation for the casting process is minimal. As discussed previously, the electricity utilisation which does occur is attributable to pumps, for manual casting, and compressors for pressure casting.

Manual casting electrical load relates to only 1-3 per cent of instantaneous site demand. This value is considered to be too small to justify detailed regression analysis and would contribute little towards obtaining a predicted profile of electrical demand on a site level.

However, pressure casting represents an area of greater significance in terms of electrical demand due to the technique requiring compressor equipment. This contribution can be seen through the analysis work carried out on compressors in chapter 10.

Compressors are an area for which the prediction of kW capacity installed is very difficult. Compressed air is used for a variety of purposes on various sanitaryware sites. The uses include slip pumping, glaze spraying, cleaning slip lines, and pressure casting. The extent to which any one site utilises compressed air for these end-uses varies considerably in accordance with site layout, site size, pressure casting levels, and company policy on back-up systems and usage.

Lighting represents another area of electricity utilisation which varies considerably in terms of proportional kW demand and electrical SEC. Again, factors other than throughput such as site layout, levels of natural lighting, and company policy impact greatly on overall kW demand. Lighting was seen through the survey to vary in terms of SEC from 0.43-1.48 GJ/t, and from 7-25 per cent of annual kWh consumption. In terms of instantaneous demand the lighting load across all sites surveyed ranged from an average of 12-33 per cent of total site kW demand, according to time of day and nd-use technology mix.

Industrial Sub-Sector DSM Decision Support System

The survey of the UK sanitaryware industry has revealed valuable information on the timing of and magnitude of electrical loads related to various process areas and end-use technologies. Further valuable information has been obtained on the attitudes towards, and likely participation in, DSM or energy services marketing with respect to various programmes.

The information obtained provides a valuable starting point at which to assess the potential for DSM/ESM with respect to the optimisation of network assets for the distribution business, or increased margins on supply contracts for the supply business.

In order to make this information readily accessible and of enhanced value to electricity utilities it is desirable to integrate all of the acquired information into a PC based database. The database would contain information on the specified industrial sub-sector, in accordance with the framework of Chapter 7, in the following subject areas:

- Historical manufacturing output levels, import and export sales trends, and forecasts of future movements in both export and import markets.

- Categorisation of manufacturers in terms of volume throughput, market share, and product specialisation.

- Analysis of energy utilisation at a process level, in terms of fuel type and magnitude and timing of demand.

- Classification and utilisation levels of end-use technologies, including information on magnitudes and timings of fuel demands and on future technology trends.

- Information on the energy and business related needs of the customers within the industrial sub-sector; enabling market segmentation of customers within the sub-sector and allowing the development of DSM/ESM programs, and subsequent targeting of these programmes, to relevant customers.

Visual Basic and Microsoft Excel have been utilised in order to provide an insight into the development of a front-end application which could be utilised to assist with DSM/ESM planning at an industrial sub-sector level. The programme has used excel macros and OBLE's (Object Linking and Embedding) in order to facilitate data exchange between the two applications.

The author, having limited time and prior knowledge of programming in Visual Basic, has endeavored to provide an insight into the likely format and operation of the proposed DSM/ESM decision support system. Figure 12.12 outlines the likely format:

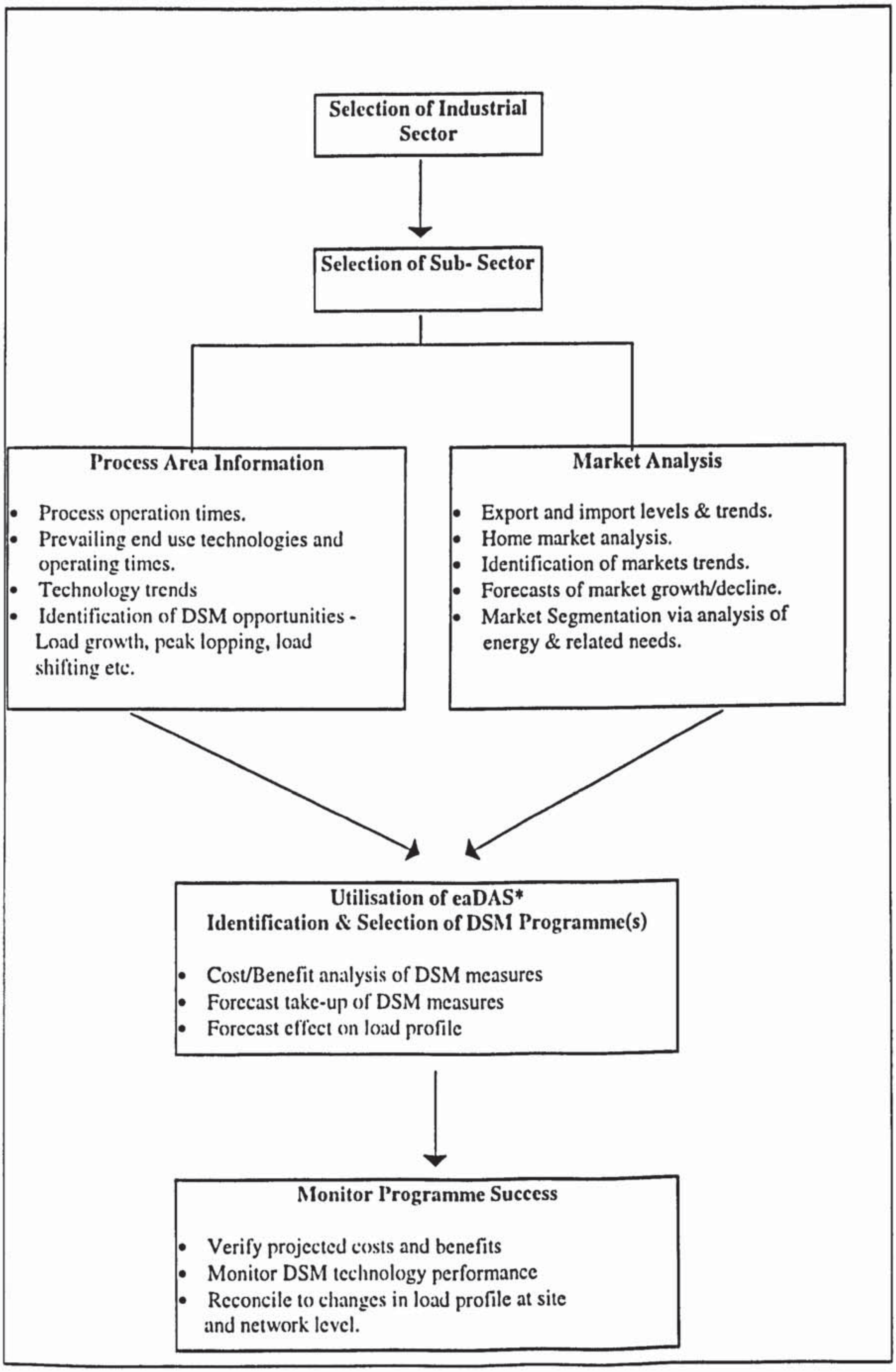

Figure 12.12 : Proposed Structure of Industrial DSM Database

It is envisaged that the information provided in this database would be used in conjunction with DSM assessment software developed by EA Technology for Midlands Electricity, the sponsor of this thesis. The particular software referred to is known as 'eaDAS', representing 'electricity association Dsm Assessment Software'. This software package allows a full cost-benefit analysis of a proposed DSM programme from several perspectives, providing information on environmental emmissions, utility costs and savings, and customer costs and savings. The software requires a range of information related to utility investments, electricity prices, market sizes, and end-use technologies. It is believed that the more detailed and relevant information provided by this study can provide increased levels of accuracy and cost-effectiveness through an intimate knowledge of the sub-sectors technologies and technology trends as well as energy related needs.

An insight into the visual appearance of the program is provided in Appendix B.

CHAPTER 13

CONCLUSIONS

Conclusions to Background Work – Chapters 2 to 6.

Chapter 2 revealed that DSM was seen to originate in the United States in the late 1970's to early 1980's in response to a threatened shortage of generation capacity, brought about by high interest rates, and prevailing high energy prices seen through what was known as the 'oil crisis'. By 1992 the US power industry had invested over $2,550 million in DSM programs.

This high level of investment in DSM was, it has been revealed, facilitated by a number of drivers:

- Prevailing high interest rates of the early 1980's were not conducive to large capital investment projects such as power stations.

- The focus upon deferring investment in generation capacity led to high levels of DSM revenue being available to achieve this aim.

- US utilities were seen to operate as monopoly providers within an integrated structure. This allowed a full transfer of the detailed information on the various parts of the supply chain from generation to end-use consumer. The level of integration enabled companies to plan such DSM programmes more effectively.

- US regulation is carried out at state level by commissions. The commissions have representatives from diverse backgrounds representing the interests of many groups. As such lobby groups such as environmentalists were able to have a much greater influence over regulatory policy.

- US regulation is carried out under the Rate of Return system. This process allowed regulatory commissions to readily account DSM expenditure as a part of the electricity utility's capital cost base, ensuring DSM expenditure achieved a return equivalent to supply side investment.

- Some US regulatory commissions allowed a rate of return on DSM investment which was greater than that achievable through supply side investment, increasing the probability that some utilities would overstate DSM program expenditure and benefits.

Each of the above drivers was conducive to investment in DSM. Within the environment created by the above factors, DSM thrived to the extent that several US commentators suggested that DSM was actually being used inappropriately and was becoming the more expensive option when compared to the alternative of supply side investment. Further, it has been found that most US DSM programmes prior to the creation of a competitive environment were actually not very successful. Many were characterised by low levels of participation and savings. However, it is true that commercial and industrial DSM programmes were more cost effective than those in the residential sector.

Chapters 3 to 5 have essentially led the author to conclude that the UK electricity industry will be unlikely to witness, in its current form, the levels of expenditure in DSM that have previously been witnessed in the US. There are several reasons for this:

- The UK has a surplus of generation capacity. At present generation capacity outstrips demand by 15 to 20 percent. As such, there is likely to be no investment in DSM by generation companies until this surplus margin is eroded.

- UK regulation is essentially carried out by an individual. It is more difficult for lobby groups that may promote DSM to have their views considered and implemented.

- The UK electricity regulator has suggested that investment in DSM is an issue that should be considered at government level and that increasing allowed expenditure beyond that provided indirectly through the Energy Saving Trust should be a matter of legislation.

- Capital expenditure allowed by the UK regulator discounts DSM investment. As such, DSM expenditure has to be funded through revenue. Price-cap regulation drives companies towards reducing costs, particularly non-capital expenditure, as they are able to retain revenues associated with efficiency increases beyond those set by the regulator.

- UK electricity utilities are able to obtain an in-built return on capital investments, such as transformer upgrades, which are thus seen as relatively low-risk. DSM investment requires utilities to take a relatively higher risk through exposure to an investment option in which they have little experience or guarantee of success and financial return. This is,esentially, a consequence of price-cap regulation.

- Volume Drivers : the volume driver on the distribution business of UK RECs directly links increased revenues with increased sales. Although this volume driver is now only 50% of allowable revenue per kWh, compared to the previous level of 100%, the net effect is to penalise investments by RECs in energy efficiency and hence DSM through loss of associated revenue.

- Disintegration of the UK electricity industry makes the planning and co-ordination of DSM, or Least Cost Planning (LCP), very difficult. The information required to facilitate DSM is often not held entirely by one area of the REC business. In order to practice DSM at a network level in the distribution business associated skills, expertise and information are required from the supply business on various aspects. The latest proposals from the regulator are to restrict the flow of information between distribution and supply by making each business area operate independently (these changes are discussed further in Chapter 4 on regulation). Specifically, the proposals are:

- Ensuring use of system contracts are formally established between Distribution and Supply.
- Avoiding the sharing of facilities between businesses, including staff transfers.
- Ensuring staff have responsibilities within the scope of one business only.
- The requirement for separate management teams for the two businesses.
- Minimising scope for corporate headquarters activity.

There are other proposed changes to the UK electricity market that have been revealed as being likely to impact upon future uptake of DSM. The first of these is the changes in electricity trading that are being proposed by OFFER. The proposals are aimed at making the electricity trading market more competitive, and therefore will by implication drive down any excess prices that currently exist. As such, the avoided costs against which DSM is seen to compete could diminish as the costs of generation typically account for up to 66% of a purchased price of a kWh by the end-user. However, the reverse could be true of DSM measures associated with peaking load and which impact only at times of system peak. These technologies may lead to DSM becoming more cost-effective as the proposed clearing market for spot-purchases of electricity at the margins of electricity supply company requirements could increase in price. On this basis DSM could compete more effectively against increased avoided costs of electricity purchase.

A further proposal which could encourage the implementation of DSM within the UK is the EC Directive on Integrated Resource Planning (IRP). The proposals which could potentially have the greatest impact on DSM are:

1. establish procedures whereby electricity and gas companies periodically present IRP plans to the competent authorities to be determined by Member States.

2. examine whether the economic energy efficiency measures identified by the IRP plan are undertaken.

3. review existing legislation in this area to ensure that mechanisms are established which permit electricity and gas distribution companies to recover expenditure on energy efficiency programmes provided to consumers. Such mechanisms should ensure that distribution companies which undertake DSM are not revenue losers.

4. promote the integration of DSM options into capacity tendering procedures in the distribution sector where these exist.

The Council Directive, in the form stipulated, will compel electricity utilities within the UK to adopt IRP in all investment decisions related to capital expenditure on network assets. This will by necessity require electricity distribution companies to have considered demand side measures as an alternative to traditional supply side measures to address network reinforcement and expansion. However, the search for a common position will require the proposal to accommodate the differences in market and industry structures between member states. As such the UK, whilst in a position whereby it already meets some aspects of the proposal, is likely to amend or reject certain aspects which it feels are incompatible with the UK electricity industry.

At present, electricity distribution companies within the UK are not compelled to put forward IRP plans when proposing investment in the electricity distribution network to the regulator. Additionally, there are no recognised revenue recovery mechanisms in place whereby distribution companies can recover revenues which are lost as a result of reduced sales associated with DSM programmes designed to defer network reinforcement. The feature of developing mechanisms whereby investment in the demand side can be recovered by electricity utilities remains an unresolved issue in the UK at the present time.

The Directive on IRP is likely to have to be compromised to take account of the industry structure within the UK. Alternatively the industry regulator will be required to reassess the treatment of capital costs and revenue recovery in order to enable the demand side and supply side to be assessed on equal terms. The exact format of the proposals, and definitive implications of IRP for UK electricity utilities, are yet to be resolved but could enable DSM to become a more effective tool in utility planning than it presently appears to be.

The obstacles to DSM presented above, which would appear to be restricting investment in DSM, are deemed a consequence of the UK regulatory system and competition. The same obstacles are now appearing in the US as a result of the introduction of competition. US electricity industry commentators have suggested that competition could spell the beginning of the end for large scale DSM and it is envisaged that DSM in the US will, in future, be:

- Service orientated.

- Move away form direct rebates and installation of measures and into the recovery of costs from programme participants, highlighting shared savings and market transformation programmes.

- Shift from residential to commercial and industrial DSM.

- Promoted where a utility fears losing customers to competition.

- Promoted where peak demand is driving investment.

The consideration of US commentators views on DSM in a competitive electricity market such as that of the UK, as given above, provided the driver to develop an Energy Services framework for implementing DSM.

Conclusions to Research – Chapters 7 to 11

The development of a framework for applying DSM via Energy Services to a particular industrial sub-sector has introduced a novel approach towards the implementation of DSM. The framework is considered to provide a comprehensive assessment of the potential for DSM and Energy Services within any particular manufacturing subsector to which it is applied.

The research undertaken in this thesis utilises the UK ceramics manufacturing sector in order to demonstrate the application of stages 2 and 3 in the framework derived in Chapter 7 (see Fig 7.1). Stages 1, 4a and 4b are beyond the scope of this thesis, being dependent upon the application of real adoption of the framework through an active programme.

The real test of the framework developed in Chapter 7 would be made through a REC accepting the importance of the role of Energy Services in the application of DSM in a competitive market. The key conclusions of Chapter 7 are:

- The application of DSM through an untargeted, or blanket, approach is haphazard and as such is likely to drive up programme costs through sub-optimal customer participation rates and a lack of knowledge of a particular customers energy utilisation. However, a lack of DSM activity in the UK on any substantive scale militates against the application of this hypothesis.

- Adoption of the framework could provide superior flexibility and benefits to both distribution and supply sides of the REC business. The framework should primarily be utilised as a tool through which the supply business can effectively move away from price focused competition.

- The knowledge of a particular sub-sector's electricity demand and consumption in relation to end-use technologies and processes provide invaluable information to the distribution business when a particular network problem has been identified.

- The framework, through focusing upon industrial sectors, takes advantage of previously obtained experiences of DSM in the US where industrial DSM has been found to be the most cost-effective form of DSM investment.

- The focus upon the energy services route negates any potential problems of cross-subsidisation which may occur. Through recovering costs from the participating company via shared savings or some other technique the REC is able to avoid politically sensitive accusations of making selected companies increasingly competitive, more competitive, than others at no cost.

- Developing the Energy Services framework requires input from various aspects of a REC business, identified as being:

  I. Network planning
  II. Marketing
  III. Customer Services
  IV. Forecasting
  V. Load Management
  VI. Regulation
  VII. Finance
  VIII. Pricing and Tariffs

- The implementation of the framework requires the user to consider the objectives to be achieved, whether the purpose is to drive Energy Services, or DSM, or both. The range of objectives far exceeds the traditional objective of DSM within a monopolistic business environment, one of increasing asset utilisation and deferring capital investment. Instead, the range of objectives fits comfortably within the competitive electricity market and addresses the criteria required for DSM to be successful in a competitive market in accordance with the view of US commentators. The objectives applicable to the framework are a combination of any of the following:

  I. Improve financial performance
  II. Promote economic development
  III. Meet the need for a reliable and economic service
  IV. Improved customer service
  V. Increased asset utilisation
  VI. Protect customer base

The application of the framework developed in Chapter 7 to the UK ceramics manufacturing sector was described in Chapters 8 and 9. Obtaining the required information is very time consuming. This was particularly true of Chapter 9 which required detailed data on the end use technologies and processes in place in the sanitaryware manufacturing. This was due to the fact that previous studies on the subject matter were unavailable and, as such, it was impossible to assess the level of replicability of electricity usage between companies within the same industrial subsector. However, this study has revealed that:

- For what is probably due to historic reasons, strong regional concentrations of a particular industrial sector exist. Ceramics manufacturing is particularly concentrated within the Midlands region. There were approximately 140 such sites within the region in 1992, consuming approximately 217 GWh of electricity or nearly 10% of regional industrial electricity consumption, which accounted for nearly 55% of UK output. This provides the local REC (Midlands Electricity plc) with strong opportunities to develop Energy Services and exploit DSM activity. Iron and steel manufacture represents, amongst others, a further example of regional concentration of a particular industry type within the Midlands region.

- At 1992 the industry's research body, British Ceramic Research Association, was predicting a long-term decline in the industry which was primarily considered to be as a result of increased overseas competition.

- Sector trends mask serious declines in particular sub-sectors. For example, the UK sanitaryware industry was seen to contract between 1987 and 1994 by over 50%. Such reductions could undermine the financial performance of the REC distributing and supplying the previously consumed electricity. This highlights the benefits of RECs working with industrial customers to reduce energy costs in an attempt to stabilise future revenues.

- Forecasts of a thriving subsector do not always come to fruition. The UK tableware sector sales grew from £420m in 1987 to £650m in 1994 and was forecast to enjoy equally successful growth rates up to 2000. However, the late 1990's have seen a contraction of the sector and the issuing of profits warnings and site closures by several major manufacturers such as J.Tams, Royal Doulton, and Wedgewood. This has mainly been put down to increased competition from overseas manufacturers and a change in consumer spending habits.

Through applying the framework constructed in Chapter 7 the conclusions on the financial and market status of the sector have revealed that the ceramics sector is, particularly on recent evidence, experiencing a period of contraction. It has been suggested (The Times 25/07/98) that the UK ceramics sector will soon enter a period of consolidation as a result of increased competition and falling productivity. The relatively poor health of the ceramics sector as at 1998, and its high density within the Midlands Electricity distribution area, makes the sector particularly attractive from an Energy Services viewpoint and as such DSM.

Research undertaken in Chapter 9 has revealed that electricity consumption within a particular subsector, namely sanitaryware manufacturing, can show minimal variation in timing and demand beyond that associated with site size and related production throughput. This is primarily due to companies utilising similar end-use technologies and processes and, more surprisingly, process start and finish times. With reference to the identified sanitaryware manufacturing process stages the main findings were:

	MWh/yr Consumed	Electricity Cost (£k/yr)	%age Site Electricity Usage	Sector Range %age Energy Usage
Material Preparation	973	39	15 %	10–20 %
Casting	224	9	3 %	1–5 %
Drying	384	16	6 %	5-20 %
Glazing	37	1.5	0.5 %	0.5-1.0 %
Firing	1382	58.5	21 %	15–25 %
Ventilation	1460	59	22 %	15-25 %
Compressors	288	11.5	4 %	3-8 %
Lighting	1890	75.8	28.5 %	15-30 %
Total	6638	270.2		

Table 12.1 : Electricity Consumption in the Sanitaryware Sector by Process Area

- **Materials Preparation**

  - Process variable load start-time 03:00 to 05:00, for a twelve hour period on sites producing in excess of 10,000 pces/wk.

  - Process variable load start-time 07:00 to 12:00 for an eight hour period on sites producing less than 10,000 pces/wk.

  - An average of 32 % of cumulative materials preparation demand is attributable to constant base-load associated with slip storage. The remainder relates to variable demand associated with blunging and pumping requirements.

  - Device numbers for the process, and cumulative capacities, have been identified and tabulated.

  - Cost effective DSM opportunities within materials preparation exist with regards to energy conservation, peak load reduction and load growth.

  - Materials preparation can account for between 10-20 % of annual electricity consumption within sanitaryware manufacture. Proportions of end-use technology consumption's within the process have been identified, along with associated operating costs.

- **Casting**

  - Casting represents an area of production with a low electricity intensity.

  - Casting loads are difficult to identify and compare. The amounts of energy expended on casting vary in accordance with site layout and type of pump utilised. Pumps have been found to run on compressed air, making any firm conclusions and comparisons haphazard and of little value.

- The attempts made at quantifying energy consumption associated with casting in this survey have revealed an average SEC requirement three times greater than those estimated in previous, less comprehensive, surveys.
- The number of UK sanitaryware sites utilising the variety of casting techniques available have been tabulated, along with the percentage of UK output manufactured. These figures were previously unknown.
- Limited DSM opportunities have been identified in terms of load growth through potential increased utilisation of pressure casting, vacuum casting, and slip heating. Conservation and peak load reduction opportunities are limited.

- **Drying**

- Throughputs associated with the prevailing drying technologies have been identified, as has the number of drying techniques. For example, chamber drying is practised on all UK sanitaryware manufacturing sites, accounting for 39 units with an average dryer capacity of 317 pieces, and a cumulative weekly throughput of 62,000 pieces.

- There is evidence of over-drying of sanitaryware in the sector. Between 50% and 70% of ware which was placed in a chamber drying for a full drying cycle was found to undergo shop drying cycles of varying lengths up to twenty four hours.
- The drying cycles associated with the various drying techniques have been identified. This has enabled electrical load profiles to be produced, along with the kW ratings of technologies utilised within drying techniques. For example, hop drying presents a considerable electrical load during overnight, off-peak hours, on all UK sanitaryware manufacturing sites. The process start-time varies in accordance with size of site. Sites operating a single shift, predominantly those producing less than 10,000 pieces per week, have a process start-time of typically 16:00 hrs. Sites producing in excess of this throughput have a typical process start-time of 22:00 hrs in accordance with the prevailing practice of a double production shift. At all sites process heat was removed at around 04:00, allowing cooling of the drying area and an eventual process finish time of 06:00. Instantaneous kW demand associated with the shop drying process can vary between 10-20% of overnight site electrical demand.
- DSM measures applicable to the drying stage have been identified and consist of conservation, load growth, and peak reduction. Annual operating costs associated with the process of shop-drying and resultant financial impacts of DSM measures have been provided.

- **Firing**

- The total numbers and types of kilns utilised in the UK sanitaryware sector have been identified for the first time. In total, forty kilns are in operation. Twenty two tunnel kilns, 17 first fire and 5 refire, have been identified, all fired by gas. Eighteen intermittent kilns are in operation, 13 first fire (3 electric) and 5 refire (all gas fired).

- The research has revealed that electricity consumption associated with intermittent kilns typically represents 10% of annual consumption. In addition, end-use technology ratings and numbers have been identified. Intermittent kilns can account for up to 20% of instantaneous demand on sites producing less than 10,000 pieces per week. Process start-times for this technology can vary due to batch operation of the kilns when full. However, batch operation does provide flexibility in process start times which can be an opportunity for the practice of DSM.

- It has been found that intermittent kilns are prevalent on manufacturing sites producing less than 10,000 pieces per week. This class of manufacturer accounts for 75% of intermittent kilns in operation.

- A revision of kiln efficiencies within the sector has been made. It has been found that the modern intermittent kilns in operation within UK sanitaryware sites under ten years old have an average SEC value of 11.0 GJ/t, with electricity accounting for 0.51 GJ/t. Kilns in excess of ten years old have been found to have an average SEC value of approximately 16.0 GJ/t, with electricity accounting for up to 1.0 GJ/t. Re-fire intermittent kilns have been found to have an average SEC value of 24.0 GJ/t for kilns in excess of ten years old.

- First-fire tunnel kilns encountered in the survey have been revealed to have SEC values in the range of 6.0-22.0 GJ/t in accordance with kiln age. Seventy five per cent of kilns were found to have SEC values in the range of 6-12 GJ/t, with 0.8-1.0 GJ/t being attributable to electricity consumption or 6.5-17%, a considerable upwards revision on previous work.

- DSM options in the firing process have been identified as conservation (electricity and gas) and load growth. Kiln heat recovery is particularly under-utilised, with only one UK manufacturer adopting the technique. Utilisation has been as high as 30% of manufacturing sites but has been eroded by a lack of confidence in the concept due to technical difficulties associated with heat exchangers of the late 1980's and early 1990's. Cost appraisals of selected DSM measures have revealed financially attractive projects particularly through the retrofitting of HEMs.

- The firing process can typically account for up to 28% of site annual electricity consumption. Previously unknown data on energy consumption of end-use technologies within the process have been identified and operating costs provided.

- **Compressed Air**

  - The survey has revealed that over 90% of UK sanitaryware manufacturers utilise oil-injected rotary screw compressors. Capacities have been found to range from 25-300 litres per second and typically operating at 7 bar for operations excluding pressure casting. Table 9.2 provides results of the survey:

  - An operating SEC range for compressors in the sanitaryware sector has been derived. Compressors were found to have a SEC range of 0.21-0.65 GJ/t and account for between approximately 7-12% of site annual electricity consumption. In terms of kW demand compressors have been found to represent between 10-14% of instantaneous site kW demand.

- There was found to be a lack of modern control techniques on compressors at many sites. Two step modulation control was seen to be the norm, with only one site utilising micro-processor control and accurately matching supply to demand.

- A variety of DSM conservation and peak reduction measures have been identified as being applicable to the majority of compressors in use in the UK sanitaryware industry. It has been found that peak kW demands can be reduced by up to 20% through the application of advanced control systems and other measures. A cost appraisal has shown that measures can provide paybacks in the range of two to four years.

Chapter 10

During the site visits of manufacturing companies undertaken as part of Chapter 9 it was found that the ceramics sector revealed classic identifiers of a heterogeneous market requiring market segmentation. These identifiers were:

- Differences between customers in terms of their actual or potential needs from a product or service.

- Differences between what they are willing to pay for a solution to these needs.

Industrial market segmentation would, according to a textbook approach, seek to correlate these needs with the particular industry of the end-user and the size of the end-users site (Doyle). However, during the course of the research it became apparent that not all manufacturing sites, even those within the same industrial subsector of sanitaryware manufacture with similar end-use technologies and energy requirements, viewed investment in energy efficiency and the related concept of Energy Services in the same manner.

Further conversation with company representatives within the ceramics sector revealed that criteria beyond a purely energy related matter often had a strong bearing on investment decisions of any nature. These identified criteria were reinforced through researching the texts available (Armitage, MBA). The key criteria and influencing variables were identified as:

- **Company strategy & its importance & relevance to segmentation and EE**
    - **- Product Innovation**
    - **- Investment in Advanced Technologies**
        - **- Product Quality**
        - **- Product Price**
        - **- Risk Acceptance**
        - **- Public Image**
- **Company Structure and Operating Procedures**
    - **- Management Style & Cost Control**
    - **- Purchasing Policy**
    - **- Financial Assessment Criteria**
- **Energy Policy**
    - **- Control of energy**
    - **- Monitoring of energy consumption**
    - **- Maximisation of efficiency of existing production plant**
    - **- Maximisation of efficiency of existing site services plant**
    - **- Enhanced working conditions**
    - **- Knowledge of latest production equipment and techniques**
    - **- Nature of relationship with energy supplier**

These variables were placed within a needs based questionnaire, addressed to the technical directors of targeted ceramics manufacturing companies. Responses were utilised in order to develop a novel approach to the market segmentation of industrial markets in respect of Energy Services, and hence DSM, participation. The market segmentation technique of cluster analysis provided the tool through which this novel approach was implemented.

The cluster analysis procedure revealed that 8 market segments were likely to exist within the ceramics manufacturing sector. The main findings of this research into market segmentation were:

- Cluster members were found to have, as was expected, very similar needs in terms of the variables identified prior to segmentation.

- Differences between clusters on identified variables were found to show correlation with the differing levels of investment in, and attitudes towards, Energy Efficiency and Energy Services. For example, Clusters 3 and 7 (Table 10.5)

- Some clusters, for example 3 and 4 (Table 10.5), were seen to exhibit similar levels of investment in Energy Efficiency despite being identified as forming individual clusters.

- The results of the cluster analysis revealed the potential conundrum that exists for RECs attempting to implement DSM via Energy Services. For example, Cluster 7 (Table 10.5) represents companies which would appear to find energy efficiency and energy services as an unattractive proposition in any form. However, companies within this cluster could potentially represent greater opportunities for cost-effective investment in energy efficiency and DSM technologies. At the other end of the spectrum, those companies belonging to Cluster 3 (Table 10.5) show a high tendency to invest in energy efficiency and are likely to be more responsive to energy efficiency and energy services proposals yet would provide fewer opportunities for DSM measures.

- The novel approach to market segmentation that has been developed has revealed that companies operating within the same manufacturing subsector, even at 3rd and 4th level SIC code, are segmented at a different level to the classic SIC approach. Cluster 4 for example is composed of manufacturing companies from tiles, tableware, refractory, and sanitaryware manufacturing sectors.

- The market segmentation procedure developed here allows an inferred level of likelihood of participation in Energy Services and hence DSM to be derived.

- Despite the likely benefits of incorporating the segmentation approach into the utilisation of Energy Services for DSM the approach requires further development in order to become commercially viable. The author is of the opinion that the questions as were framed in the questionnaire have led to misresponse from targeted companies which may have influenced the segmentation procedure. This may be addressed through further research on the identified variables and/or the utilisation of a different clustering procedure.

Chapter 11 was concerned with a preliminary scoping study of the potential for replicating industrial subsector findings from data acquired through the site surveys undertaken. Surveying an entire industrial subsector, even one consisting of a relatively small number of manufacturing sites, is particularly time consuming and as such is probably an unrealistic task for fragmented electricity supply businesses. The work undertaken in Chapter 11 has used regression analysis in order to identify the practicalities of surveying a representative sample of companies so as to produce an estimate of electrical demand associated with end-use processes and technologies. Chapter 11 has revealed that regression analysis can be used in order to provide a sufficiently accurate insight into the cumulative kW demands associated with production processes. The findings were:

- Regression analysis of cumulative kW demand related to site throughput, as associated with the materials preparation process, revealed that a high level of accuracy was achievable through utilising the technique to predict cumulative kW demand. Further, it was found that it was possible to assign this cumulative kW demand to end-use technologies. Extending the use of regression analysis into the blunging process revealed that cumulative kW demand associated with the end-use of blunging could be predicted with a high degree of accuracy from a knowledge of site throughput. On this basis kW demand associated with the other main end-use in the process, that of slip storage, was able to be obtained. The regression technique was applied with success to other process areas of firing and drying.

- The application of regression analysis to shop drying proved to be more difficult and subject to a large degree of error when related to site throughput levels. It was found that this was primarily due to the high level of variability in terms of system design. Shop drying would appear to be something of a 'black-art' and many systems appeared to have evolved on an ad-hoc basis over time as opposed to having been the subject of thermodynamic design. As such there was little correlation between site throughput, or drying system capacity, with cumulative kW demand. The more engineering based systems such as chamber drying did, however, conform to the regression procedure.

Future Work

The final stages of Chapter 11 provide an insight into the preliminary development of an Industrial Subsector DSM decision support system. It is proposed that the system is developed in a database format, using Microsoft Visual Basic as the user interface. The system would contain information on the following:

- Historical manufacturing output levels, import and export sales trends, and forecasts of future movements in both export and import markets.

- Categorisation of manufacturers in terms of volume throughput, market share, and product specialisation.

- Analysis of energy utilisation at a process level, in terms of fuel type and magnitude and timing of demand.

- Classification and utilisation levels of end-use technologies, including information on magnitudes and timings of fuel demands and on future technology trends.

- Information on the energy and business related needs of the customers within the industrial sub-sector; enabling market segmentation of customers within the sub-sector and allowing the development of DSM/ESM programs, and subsequent targeting of these programmes, to relevant customers.

In essence, the work of Chapters 8-11 would be combined and extended to incorporate several industrial subsectors which have a high level of representation within the MEB geographical network footprint. It is believed that the results should allow MEB beneficial access to the required information to exploit DSM through Energy Services opportunities in what is thought to be the most appropriate manner to fully exploit the benefits of DSM in the current utility operating and business environment.

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2. Energy Utilisation Within the UK Sanitaryware Sector, Universities Power Engineering Conference 1998, Edinburgh.

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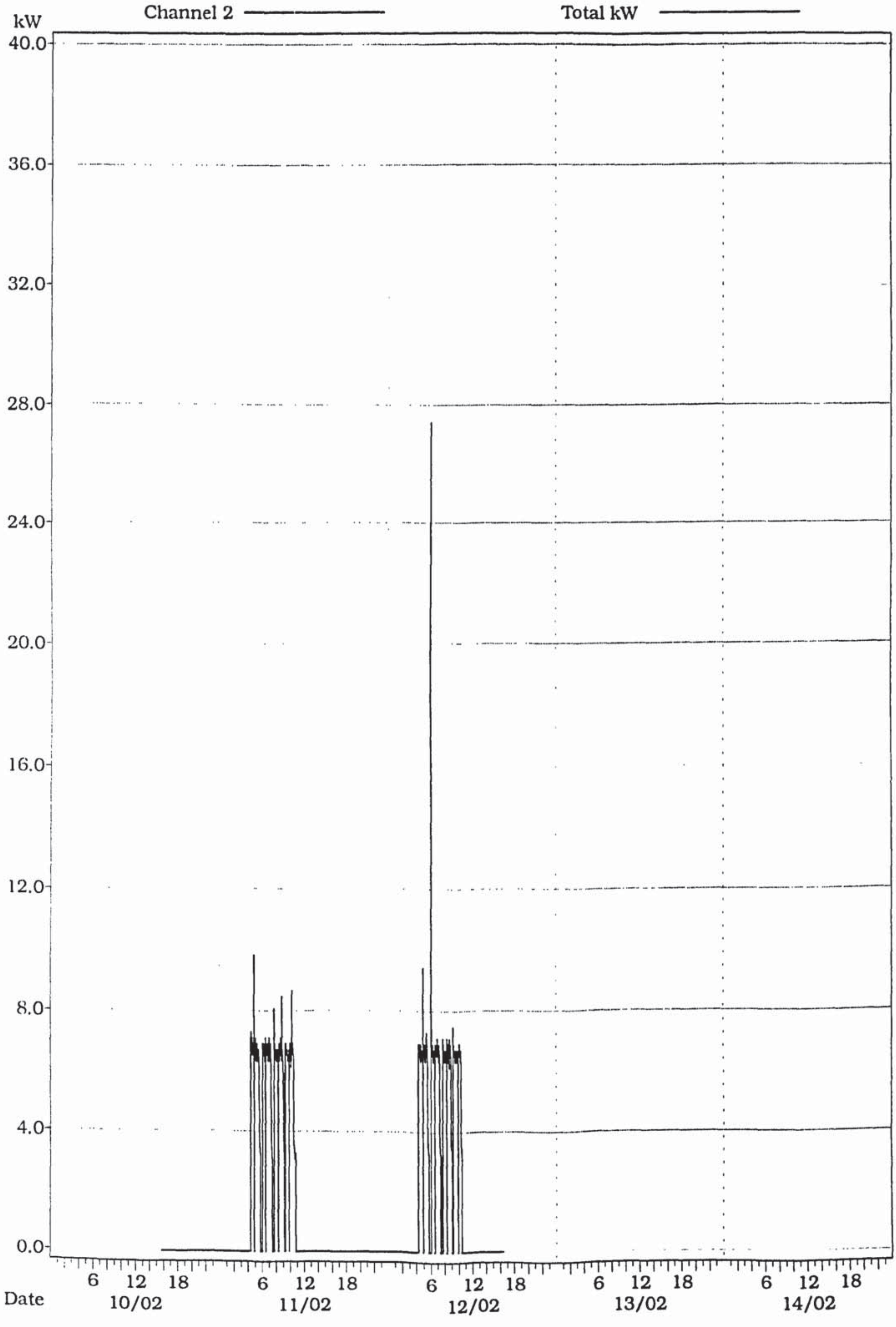
APPENDIX A

kW DEMAND PROFILES

This appendix contains the results of the on-site montitoring of a sanitaryware manufacturing site within the MEB region. The information is produced in terms of a summary sheet, detailing the type of device being logged and maximum and minimum power demands, and a profile of electricity demand over the monitoring period.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kW
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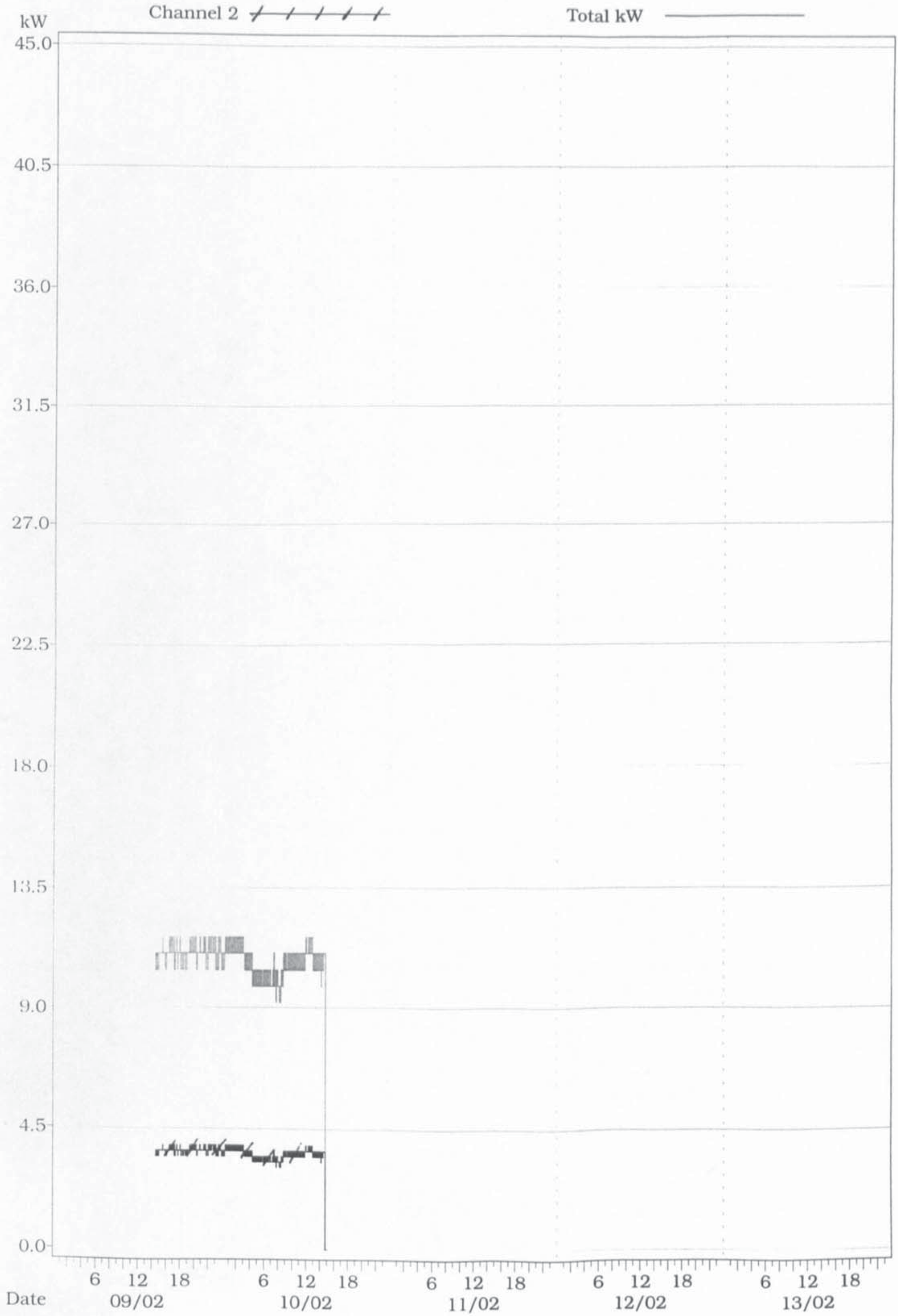
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
6 12 18
6 12 18
6 12 18
6 12 18
6 12 18
Date
10/02
11/02
12/02
13/02
14/02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kW
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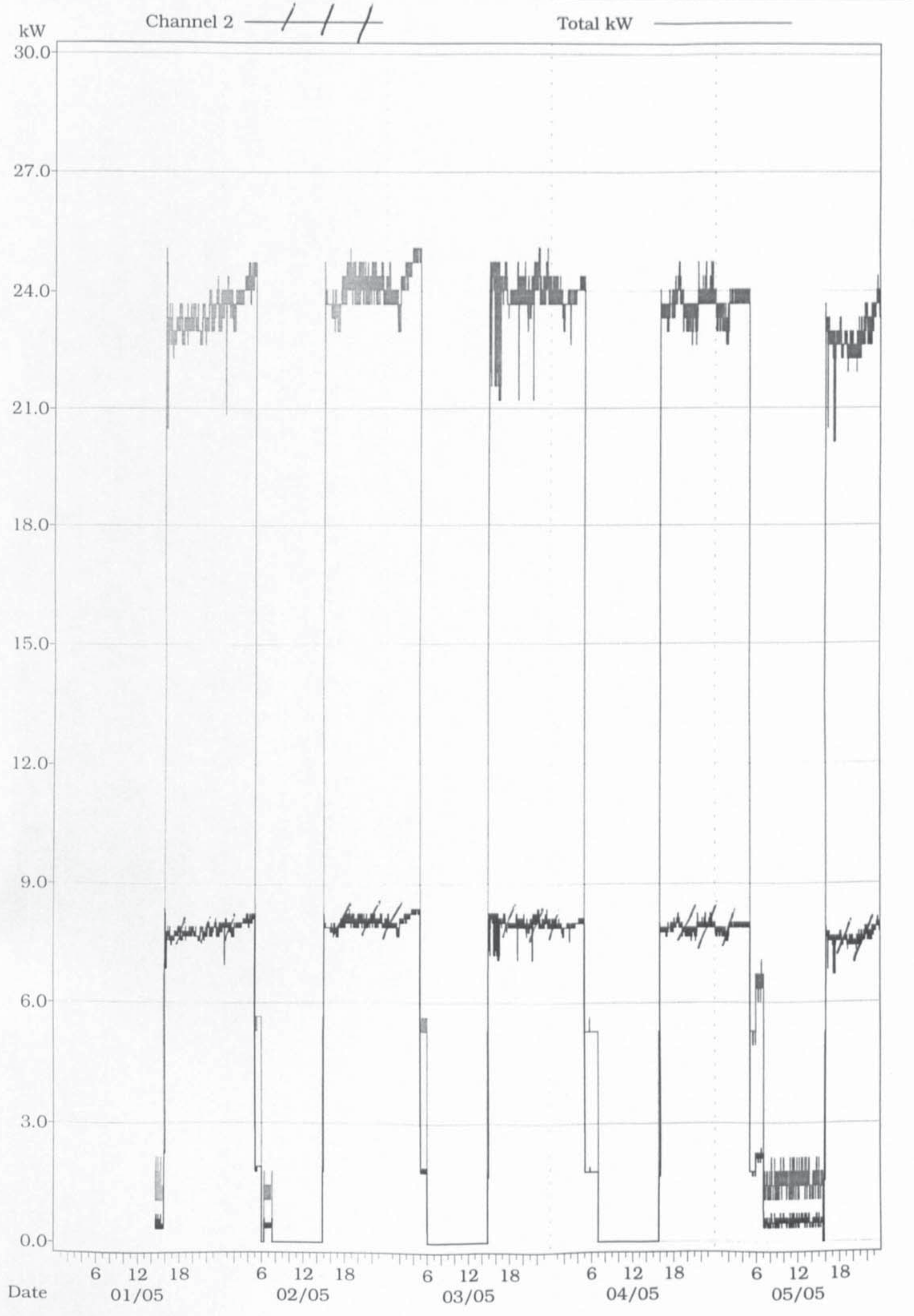
36.0
31.5
27.0
22.5
18.0
13.5
9.0
4.5
0.0
6 12 18
6 12 18
6 12 18
6 12 18
6 12 18
Date
09/02
10/02
11/02
12/02
13/02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kW
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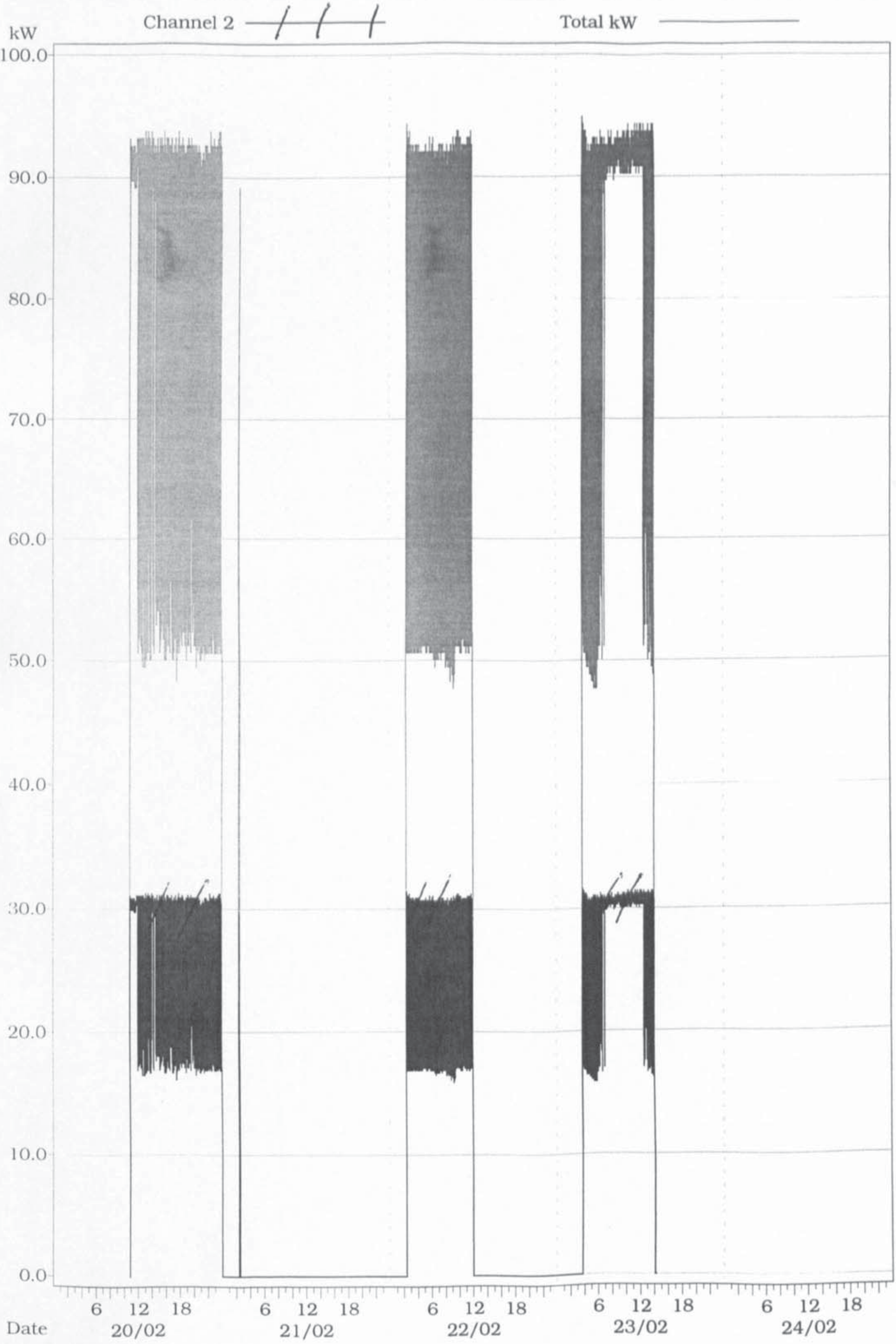
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
6 12 18 6 12 18 6 12 18 6 12 18 6 12 18
Date
01/05
02/05
03/05
04/05
05/05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kW
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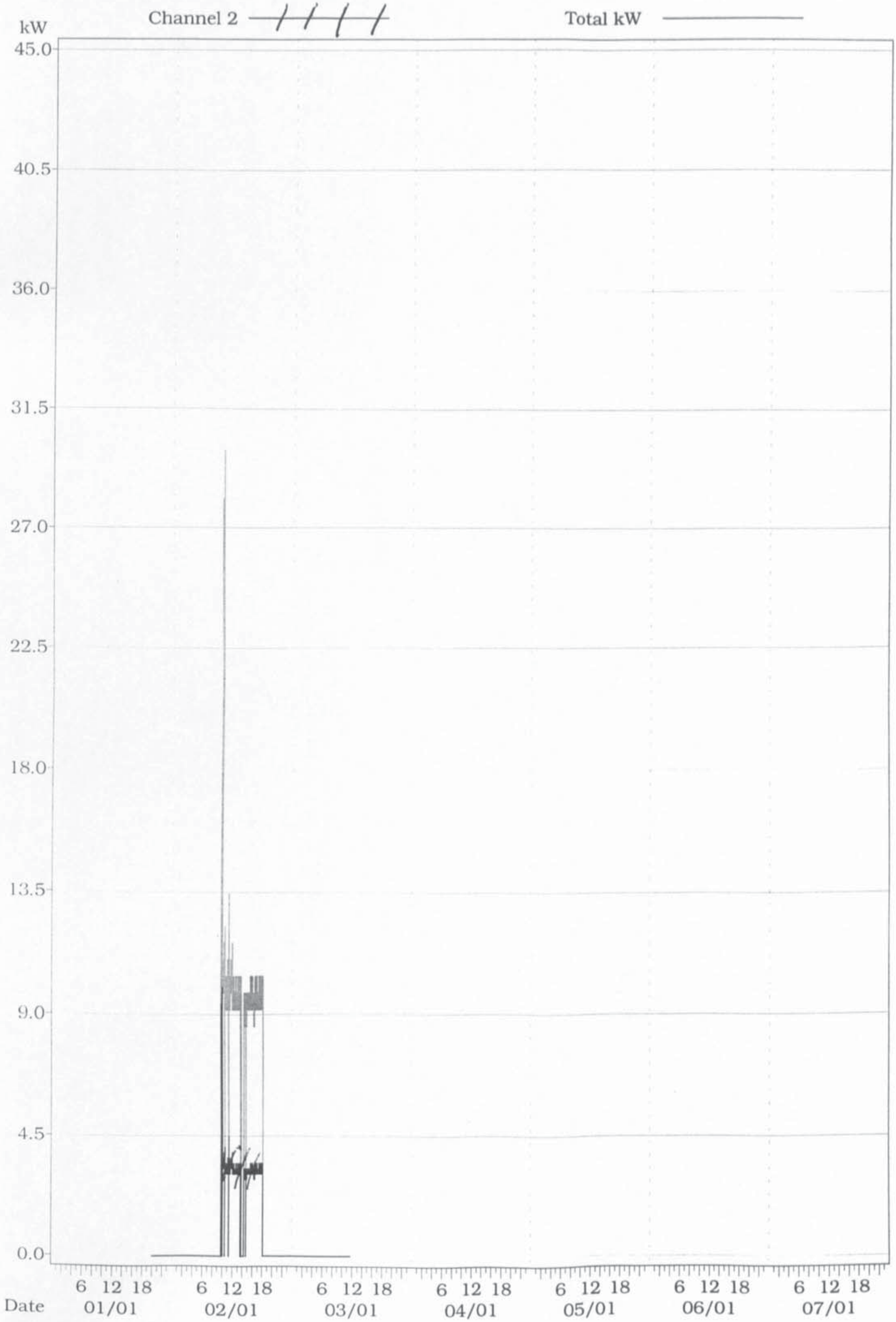
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
6 12 18
20/02
6 12 18
21/02
6 12 18
22/02
6 12 18
23/02
6 12 18
24/02
Date



Channel 2
Total kW
kW
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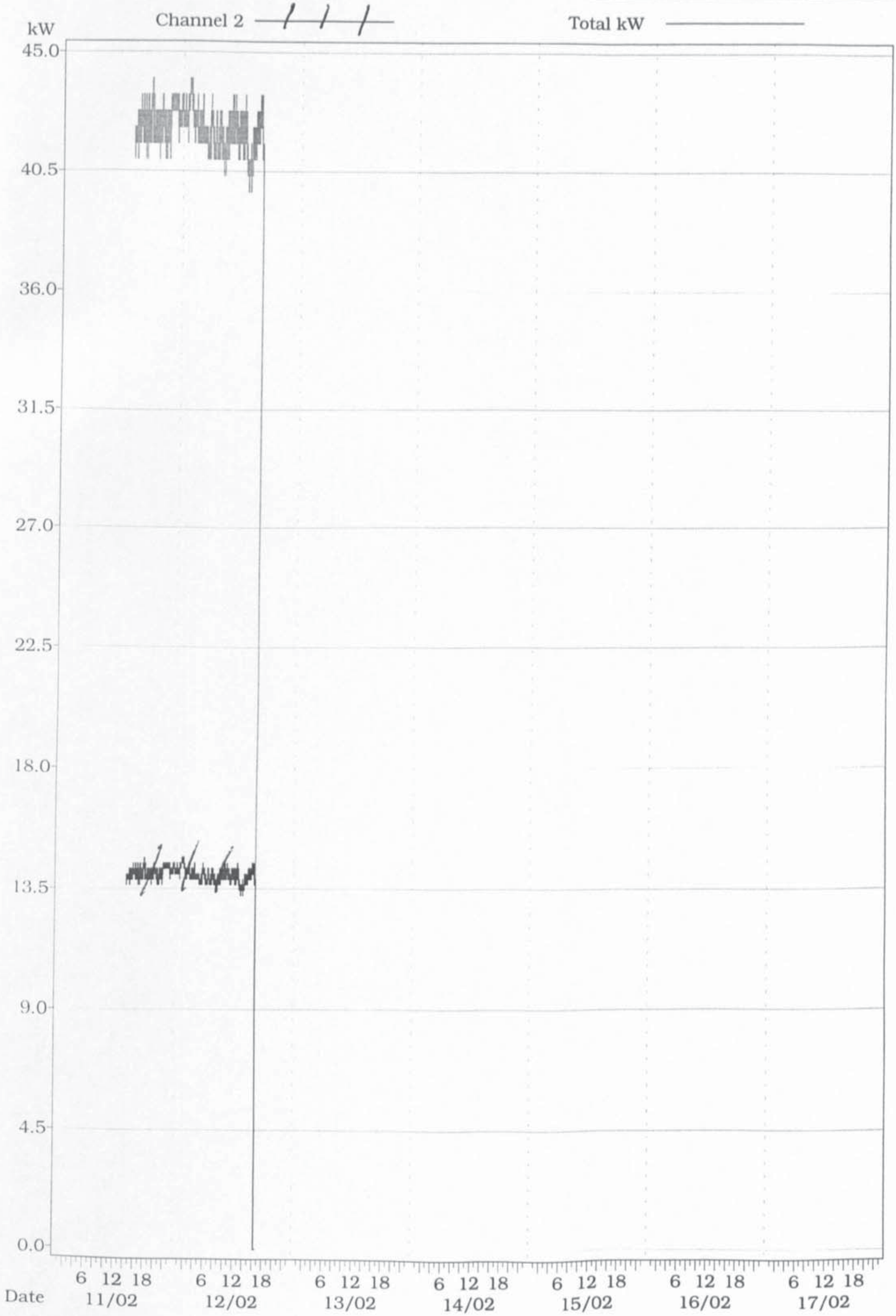
40.5
36.0
31.5
27.0
22.5
18.0
13.5
9.0
4.5
0.0
6 12 18
Date
01/01
02/01
03/01
04/01
05/01
06/01
07/01


Channel 2
Total kW
kW
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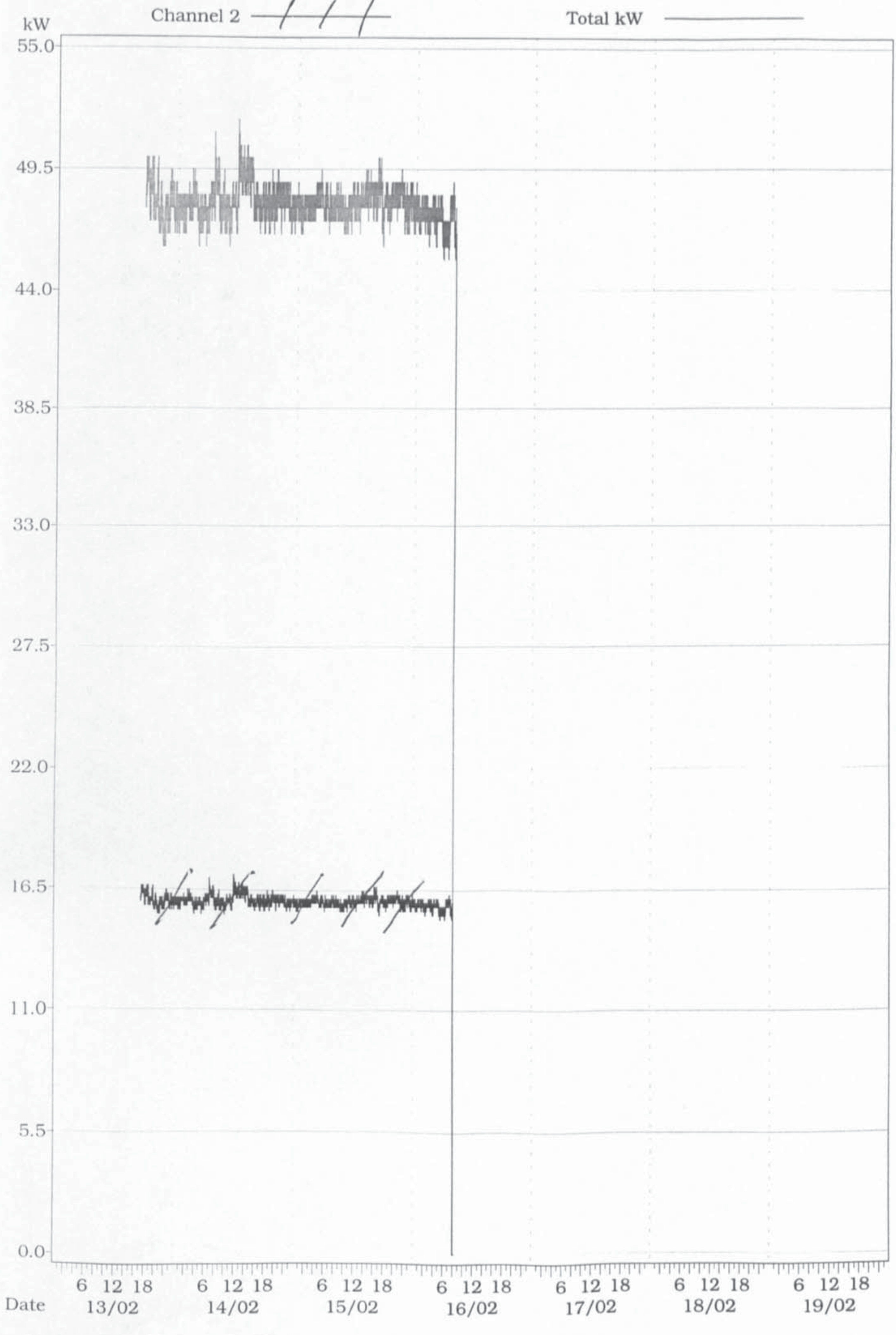
40.5
36.0
31.5
27.0
22.5
18.0
13.5
9.0
4.5
0.0
Date
6 12 18
11/02
6 12 18
12/02
6 12 18
13/02
6 12 18
14/02
6 12 18
15/02
6 12 18
16/02
6 12 18
17/02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Total kW
kW
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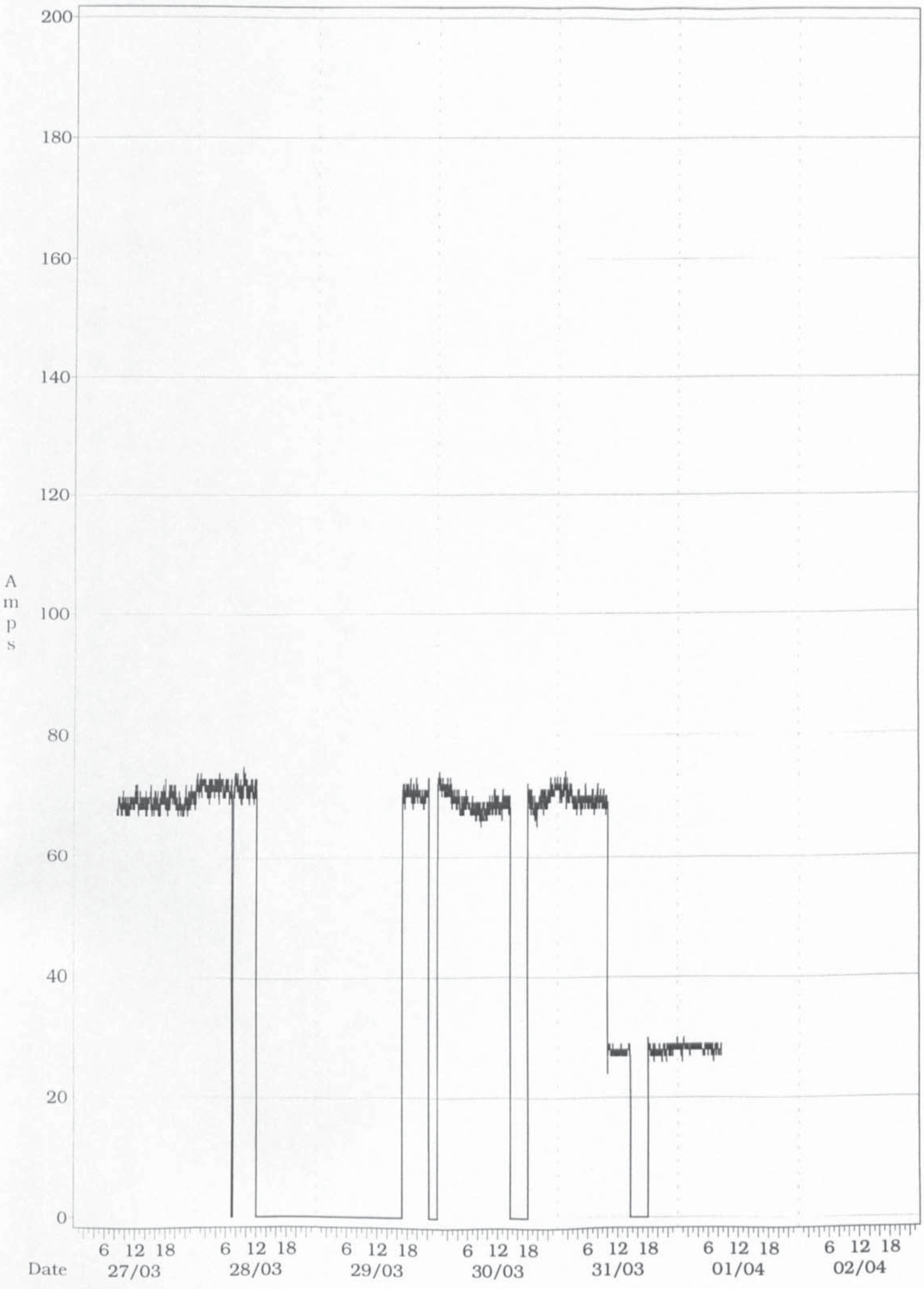
49.5
44.0
38.5
33.0
27.5
22.0
16.5
11.0
5.5
0.0
6 12 18
Date
13/02
14/02
15/02
16/02
17/02
18/02
19/02


200
180
160
140
120
100
80
60
40
20
0
Amps
Date
6 12 18
27/03
6 12 18
28/03
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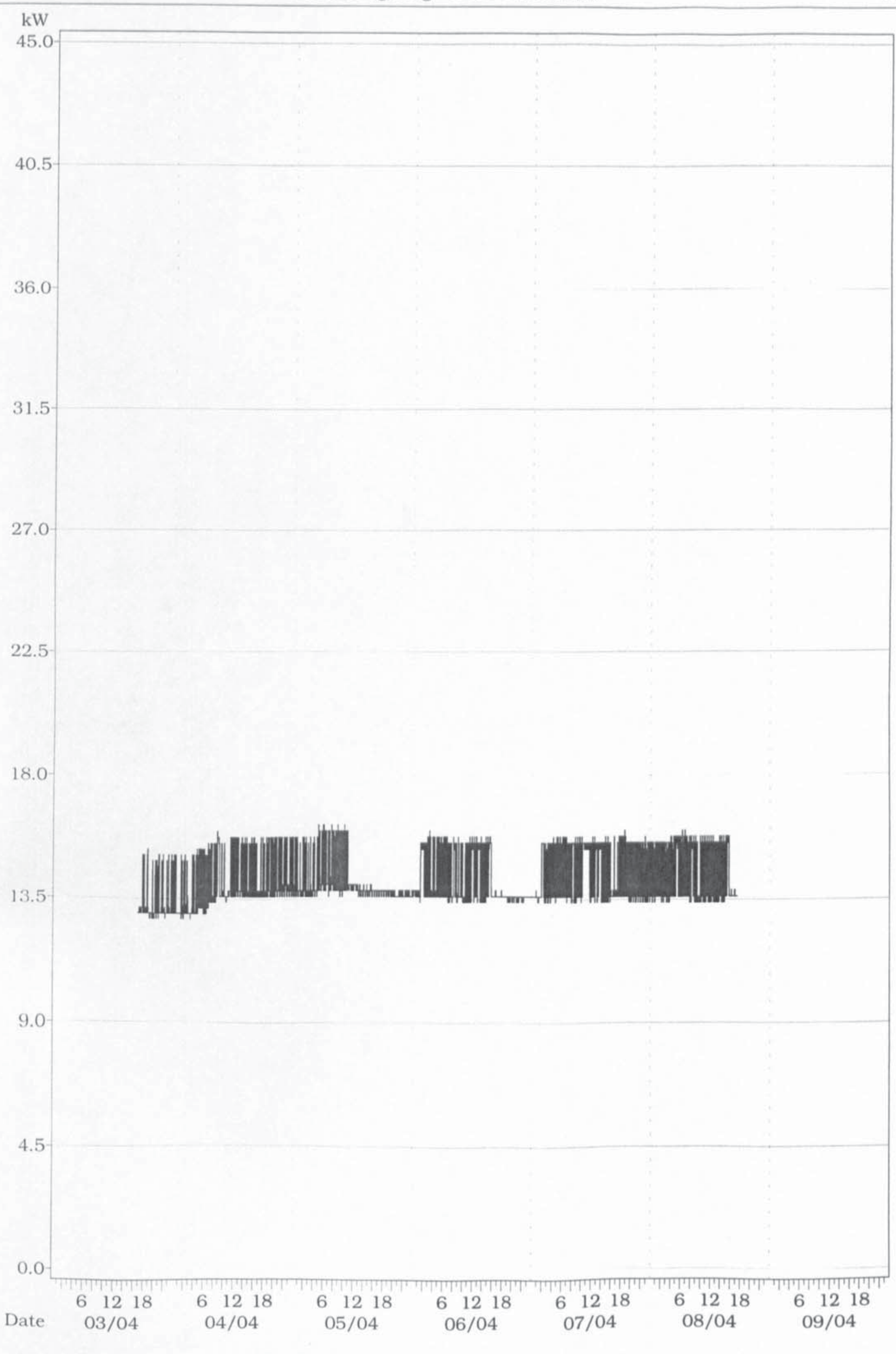
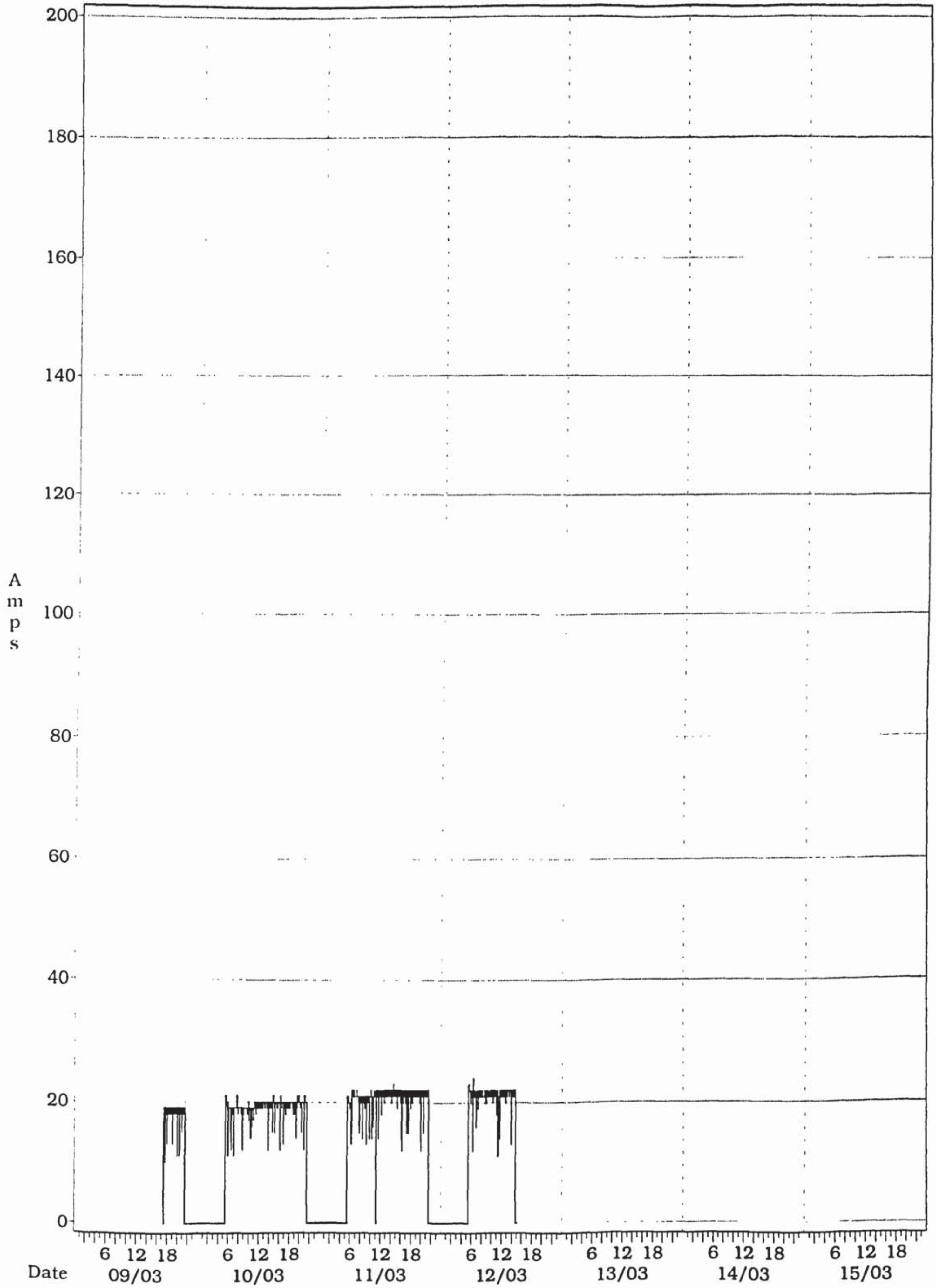
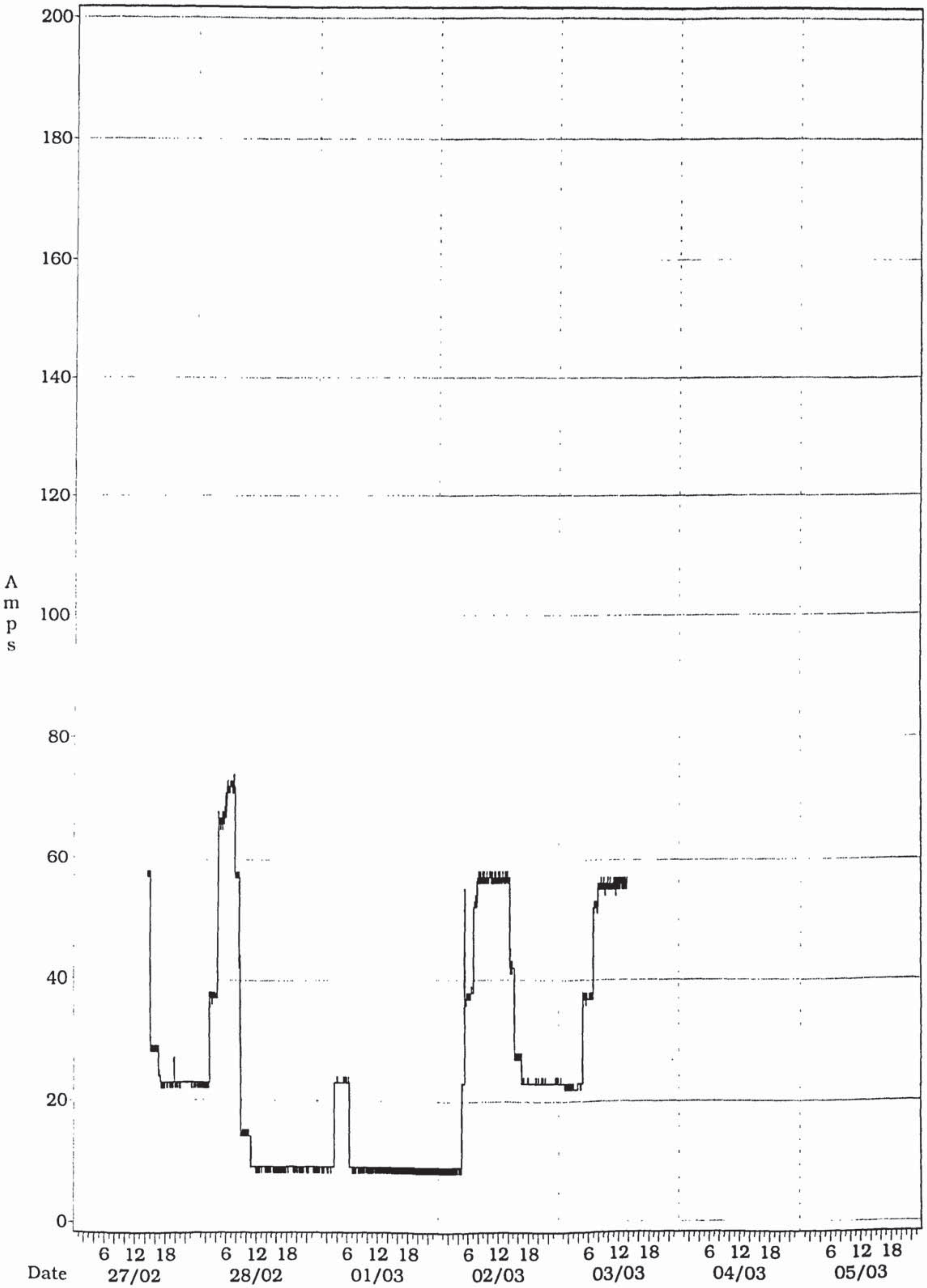
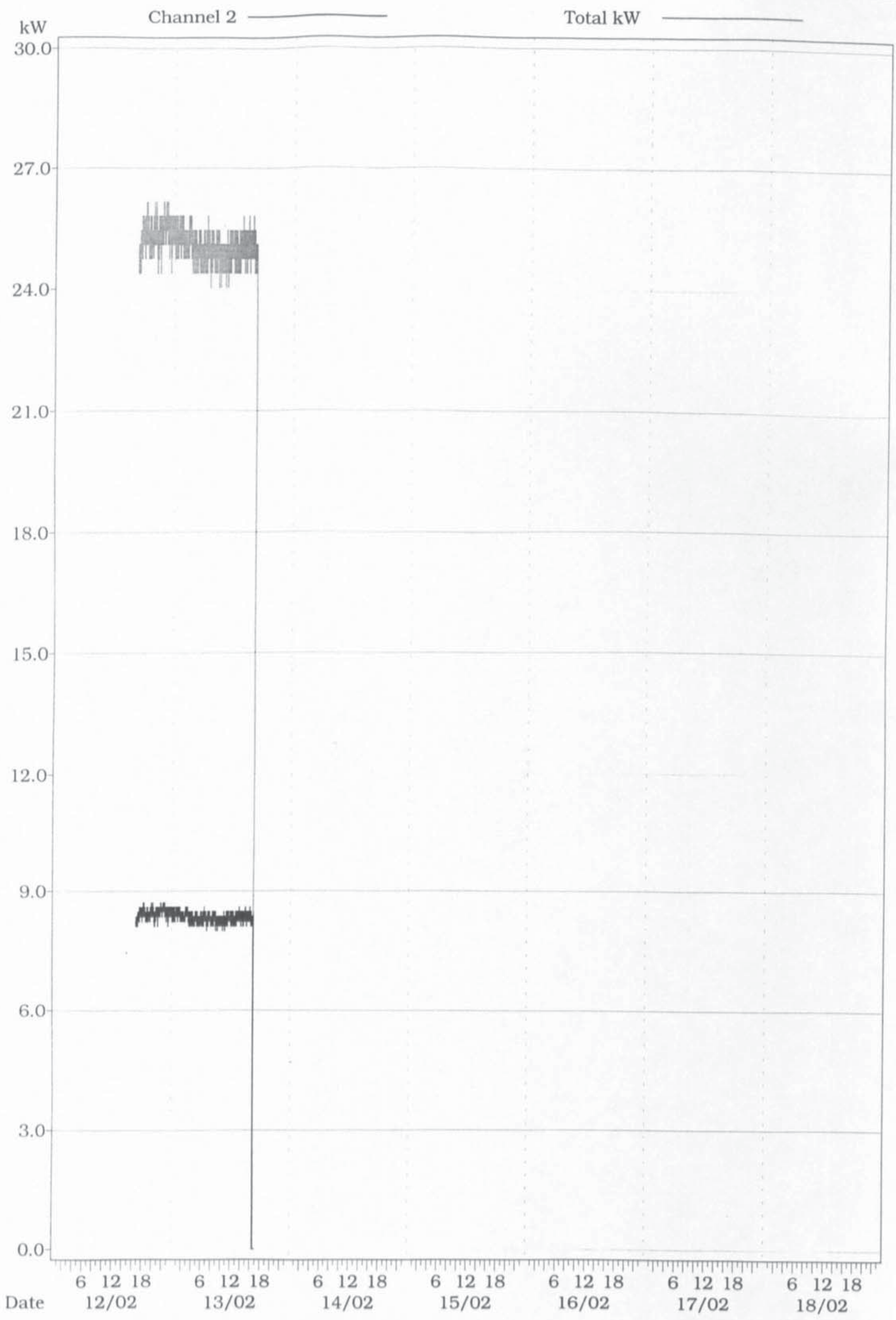
01/04
6 12 18
02/04


kW
45.0
40.5
36.0
31.5
27.0
22.5
18.0
13.5
9.0
4.5
0.0
6 12 18
Date
03/04
04/04
05/04
06/04
07/04
08/04
09/04


200
180
160
140
120
100
80
60
40
20
0
Amps
6 12 18
Date
09/03
10/03
11/03
12/03
13/03
14/03
15/03


200
180
160
140
120
100
80
60
40
20
0
Amps
Date
6 12 18
27/02
28/02
01/03
02/03
03/03
04/03
05/03



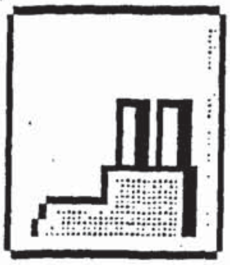
Channel 2
Total kW
kW
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
6 12 18
Date
12/02
13/02
14/02
15/02
16/02
17/02
18/02

APPENDIX B

PROPOSED INDUSTRIAL DECISION SUPPORT SYSTEM

This appendix provides a visual example of the framework of the software system that is suggested in the thesis as being an appropriate medium for the storage of industrial DSM data/. The system is designed to allow an initial insight into the feasability or potential for DSM within a specific industrial sub-sector.

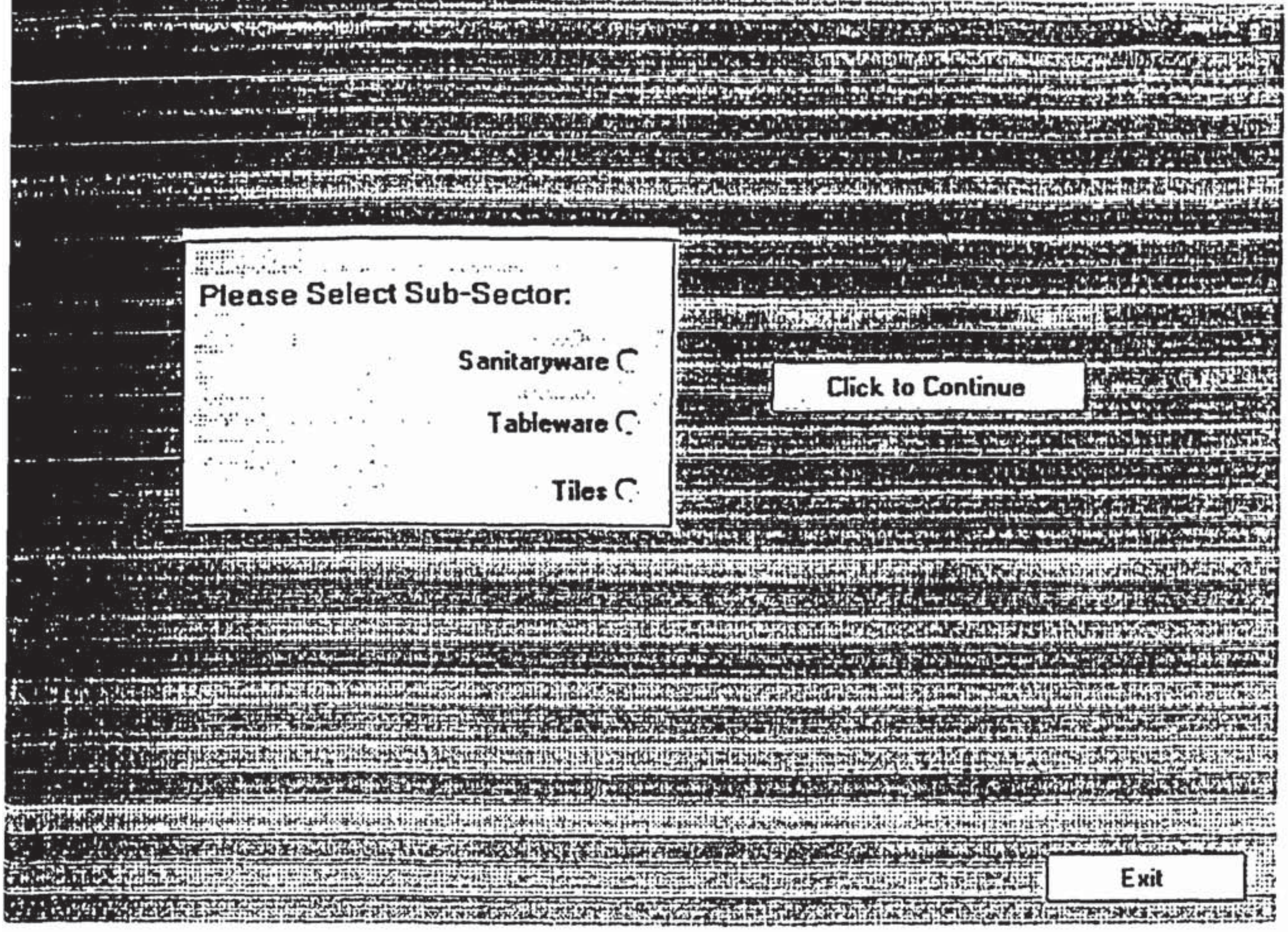
INDUSTRIAL DSM DECISION SUPPORT SYSTEM

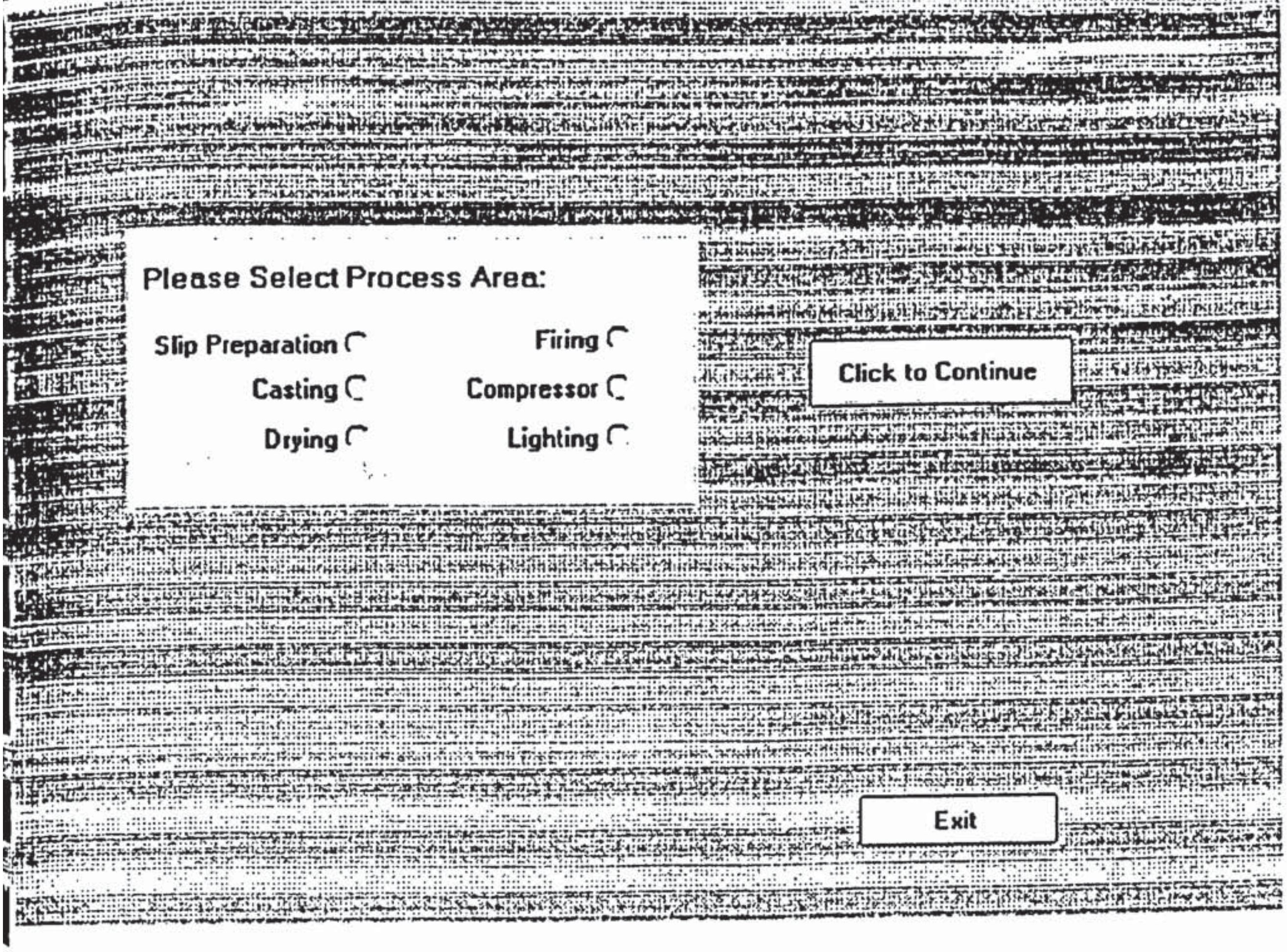


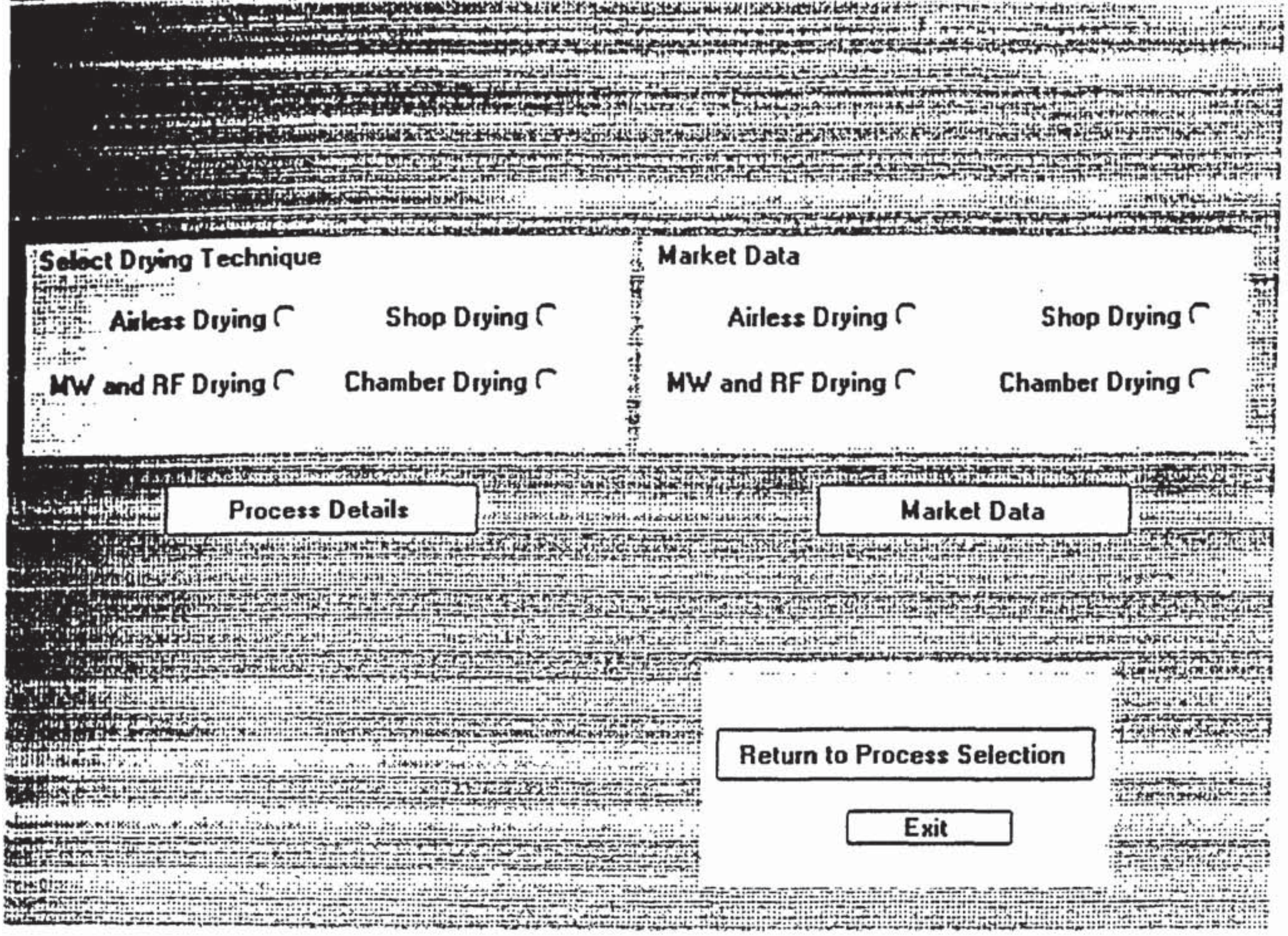
DSM OPTIONS FOR THE CERAMICS SECTOR

Click to Continue

Quit

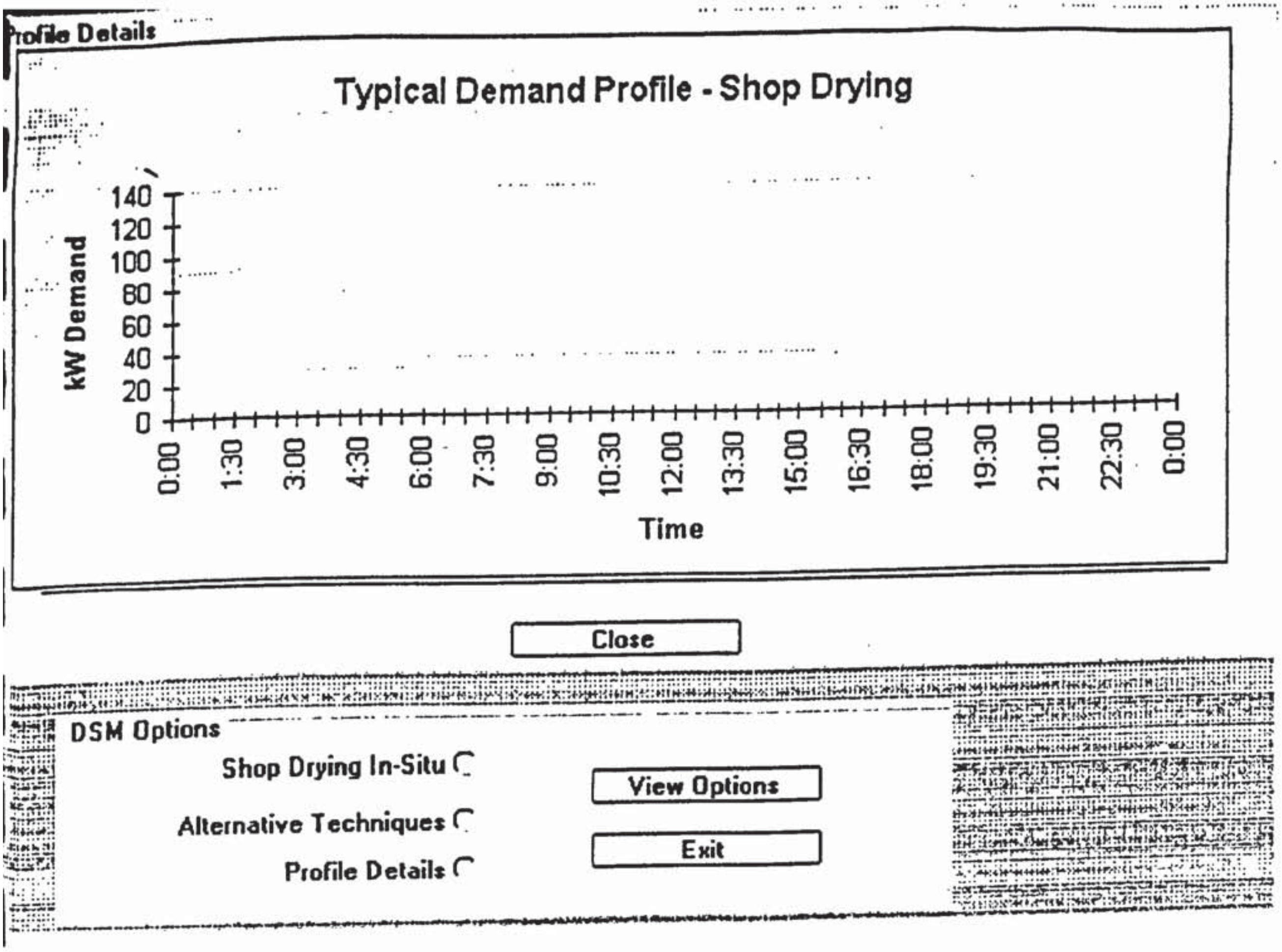

Please Select Sub-Sector:
Sanitaryware
Tableware
Tiles
Click to Continue
Exit


Please Select Process Area:
Slip Preparation
Firing
Casting
Compressor
Drying
Lighting
Click to Continue
Exit


Select Drying Technique
Airless Drying
Shop Drying
MW and RF Drying
Chamber Drying
Market Data
Airless Drying
Shop Drying
MW and RF Drying
Chamber Drying
Process Details
Market Data
Return to Process Selection
Exit

TEXT BOUND INTO

THE SPINE

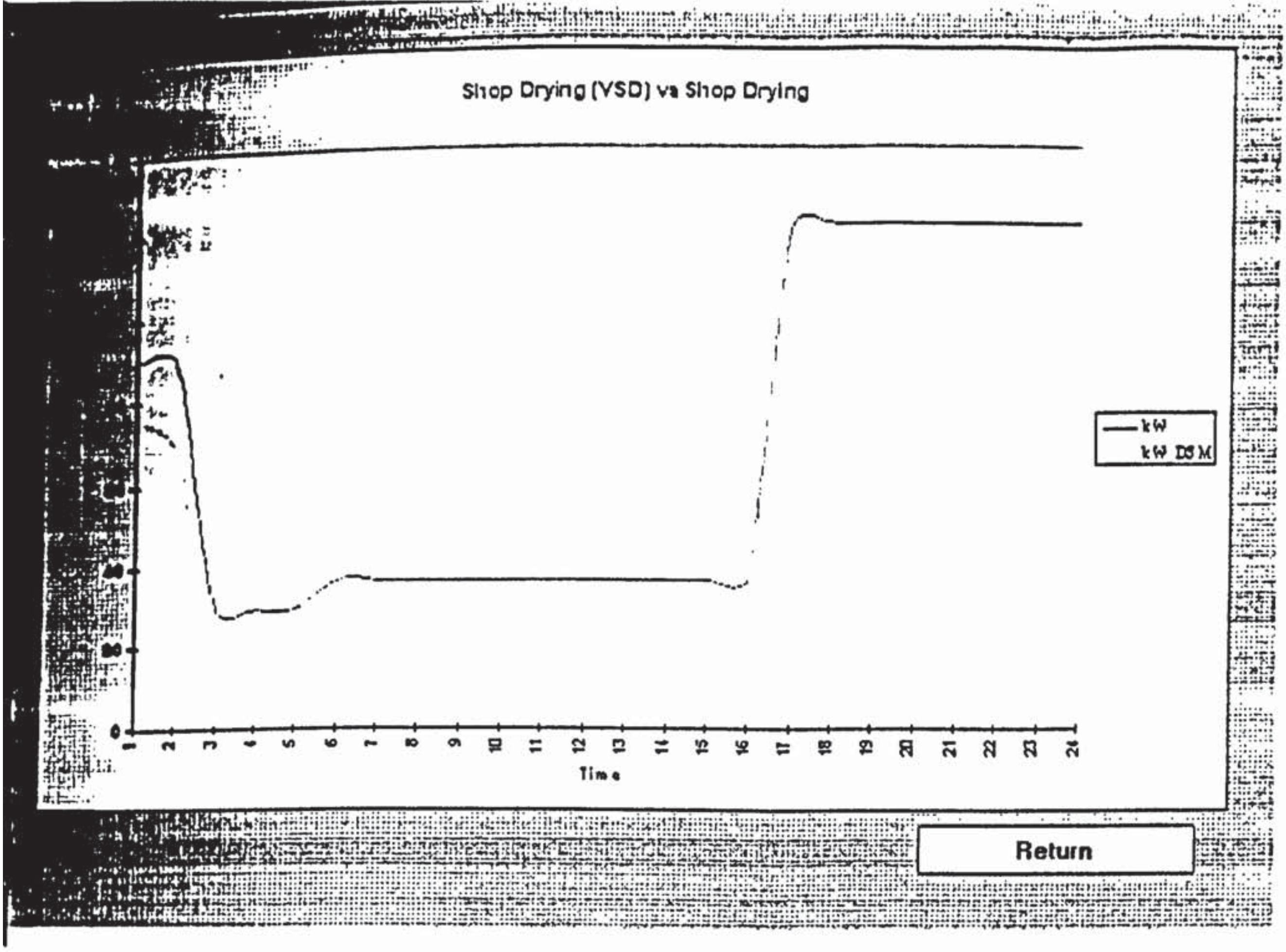

Profile Details
Typical Demand Profile - Shop Drying
kW Demand
140
120
100
80
60
40
20
0
0:00
1:30
3:00
4:30
6:00
7:30
9:00
10:30
12:00
13:30
15:00
16:30
18:00
19:30
21:00
22:30
0:00
Time
Close
DSM Options
Shop Drying In-Situ
Alternative Techniques
Profile Details
View Options
Exit

DSM Options

[illegible]	*Applicable Technologies*	*Application Area*	*Practicality*
oad Reduction	HEMs, VSDs.	Fan Drives.	Very favourable. Size of motors (1-20 kW) and the high levels of annual operation provide excellent opportunities for reducing consumption. Demand reduction is minimal, HEM installation would typically achieve 2-5% reduction in kW. VSD control on certain fan motors would achieve load reduction and reduced consumption (*see below*).
Peak Lopping	VSDs.	Fan Drives	Extract and inlet fans are typically of significant rating (10-20 kW) and damper controlled. Most fans operate 24hrs, with highest load during overnight drying cycle. The fan loading is particularly high on sites which utilise heat recovered from kilns.
oad Shifting	Timer controls.	Process Control	Long cycle times (10hrs +) lend process to off-peak utilisation. Possible to defer/advance timing of process without impacting product quality and with minimal effect on throughput. However, drying is seen by many as the bottl-neck in production, therefore may be undesirable.
ynamic Load haping			
Load Growth	MW & RF	Dryer Units	Drying considered bottle-neck in production process. Therefore potential to increase production and electrical demand/consumption through shorter drying cycles delivered by MW/RF drying, in proportion to ability to increase production throughput.

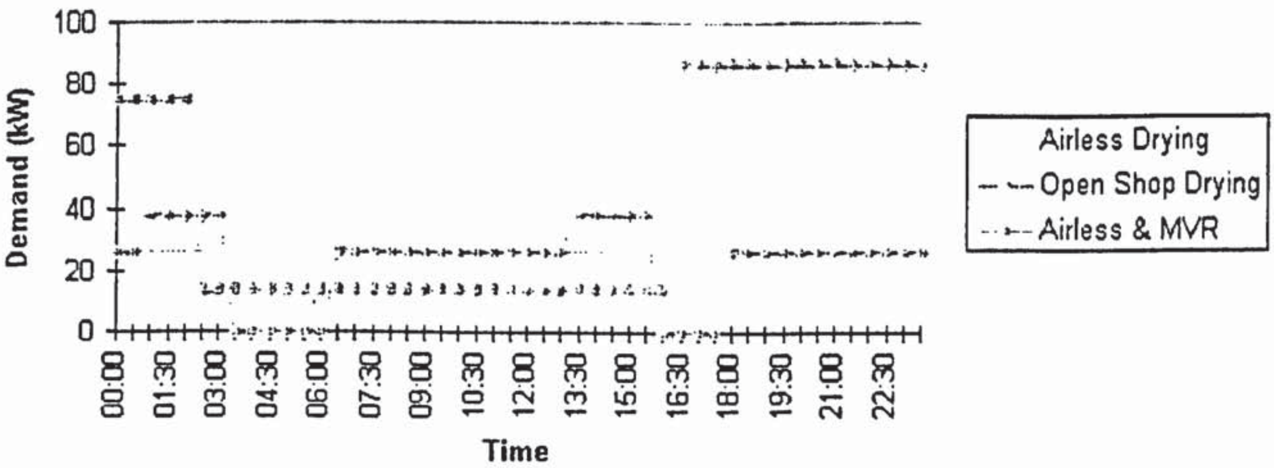
View VSD Profile

Return

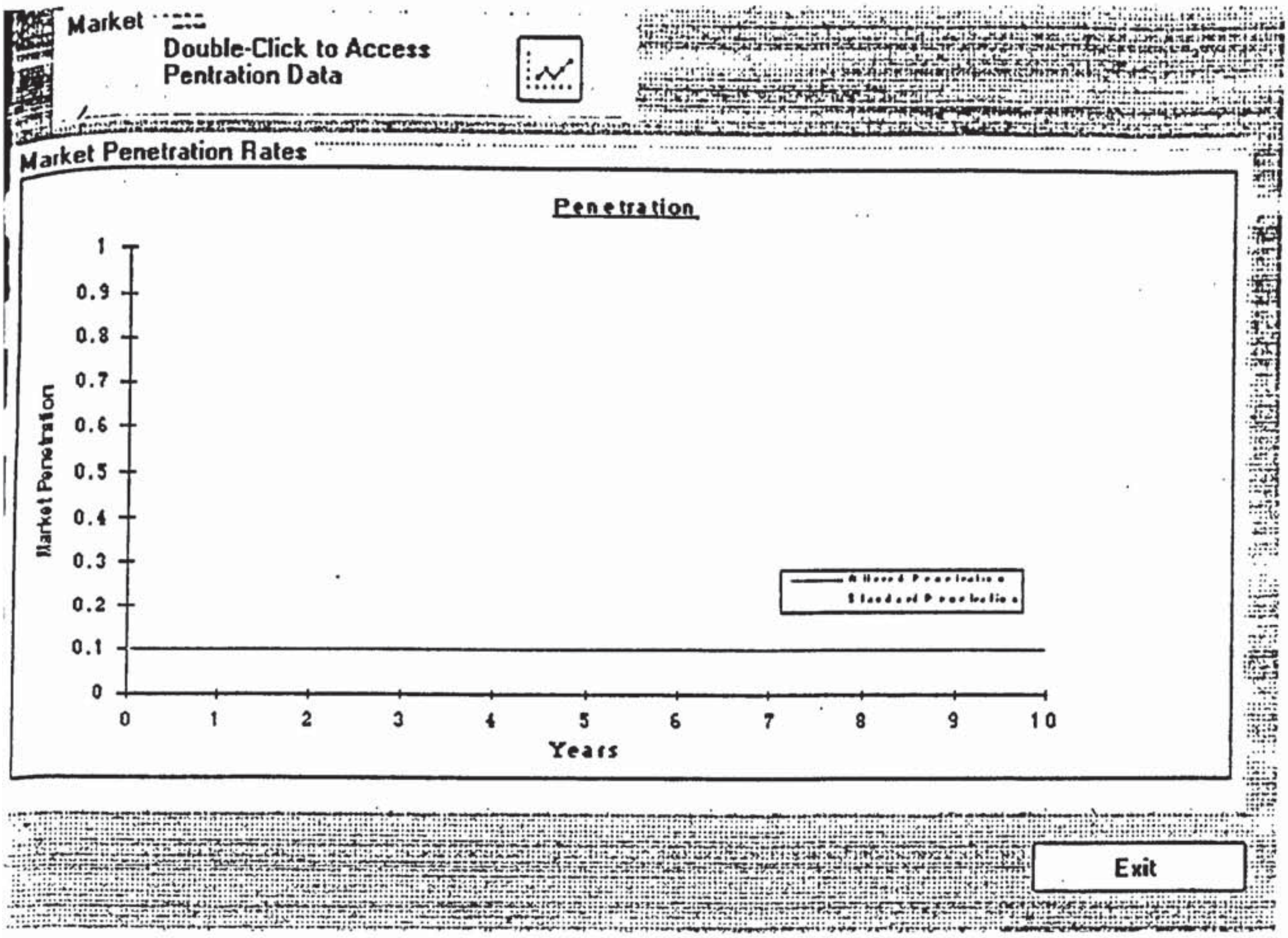


Shop Drying (VSD) vs Shop Drying
kW
kW DSM
Time
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
0
Return

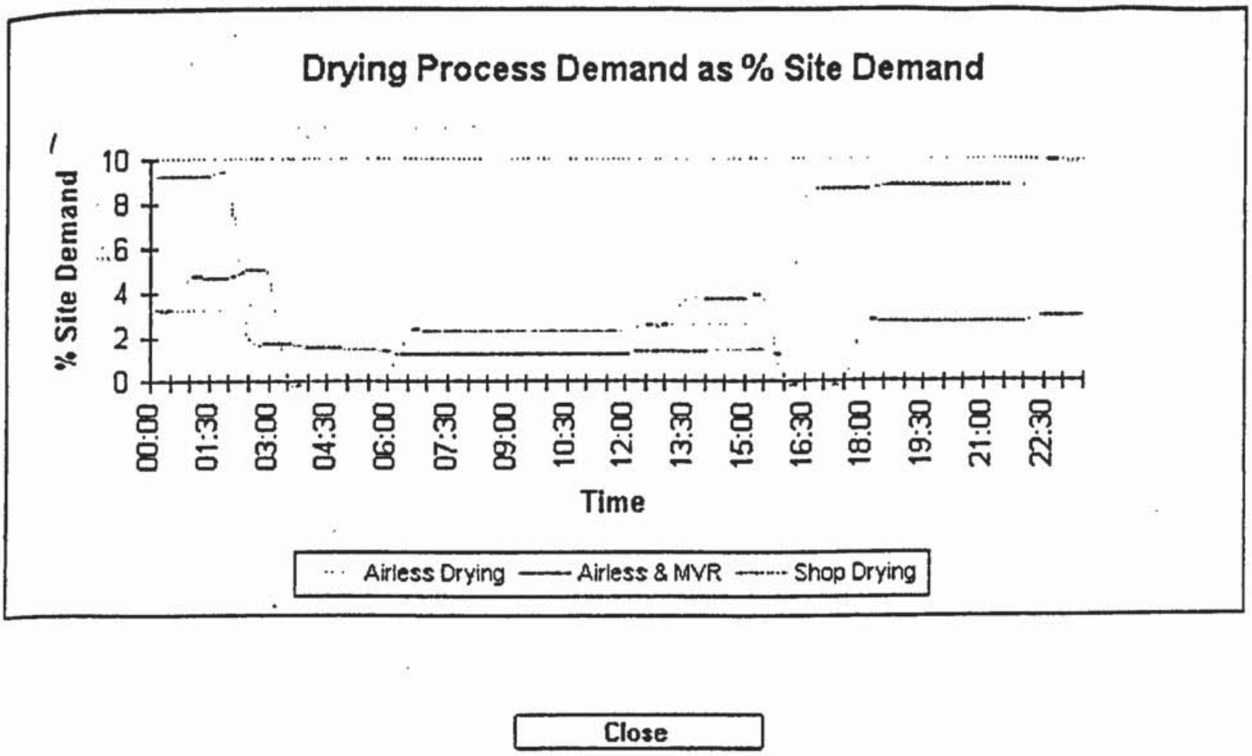
Airless Drying & Shop Drying Demand Profiles for Equivalent Product Loading

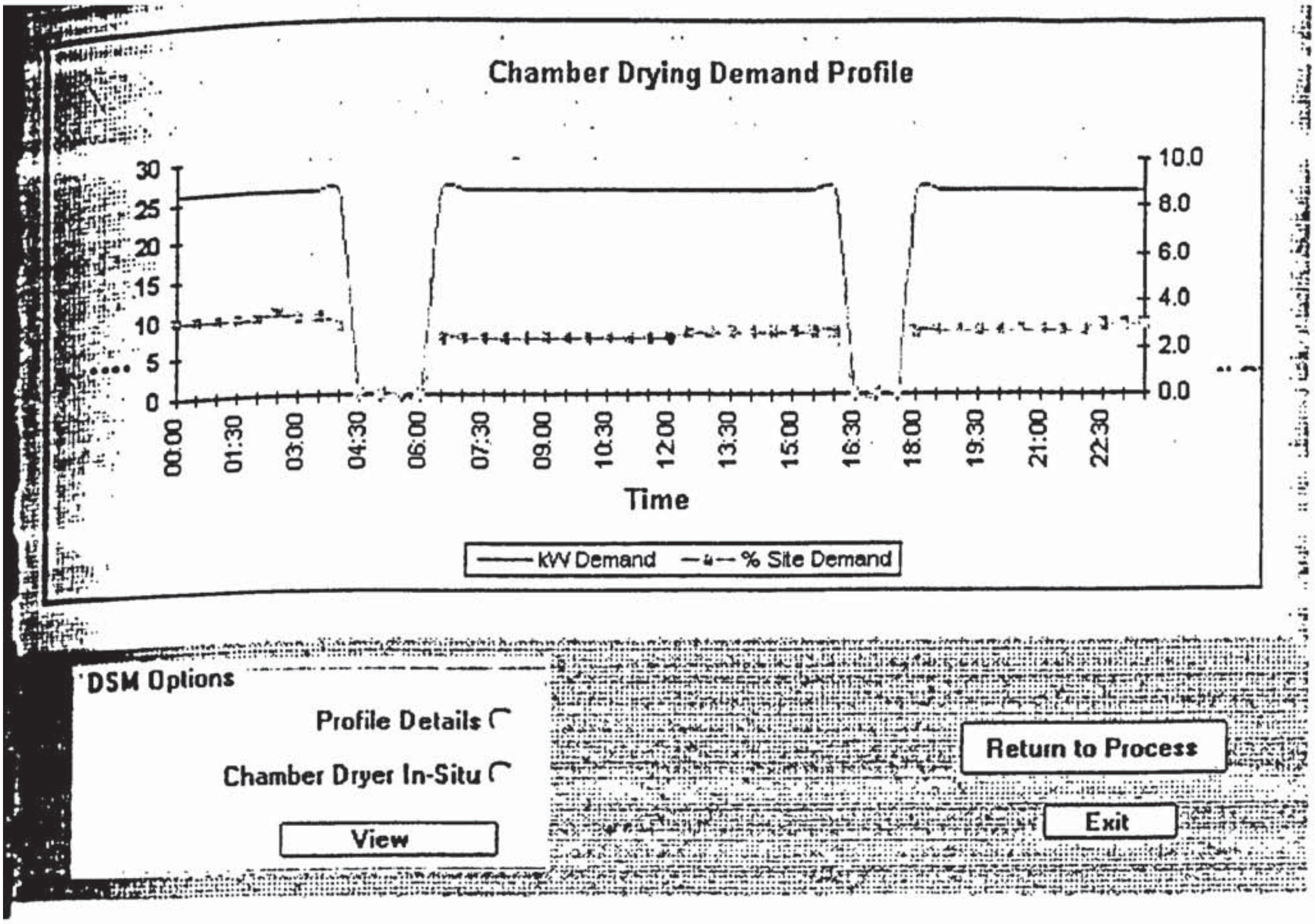


Return Shop Drying



Market
Double-Click to Access
Pentration Data
Market Penetration Rates
Penetration
Market Penetration
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10
Years
Exit


Drying Process Demand as % Site Demand
% Site Demand
10
8
6
4
2
0
00:00
01:30
03:00
04:30
06:00
07:30
09:00
10:30
12:00
13:30
15:00
16:30
18:00
19:30
21:00
22:30
Time
Airless Drying
Airless & MVR
Shop Drying
Close



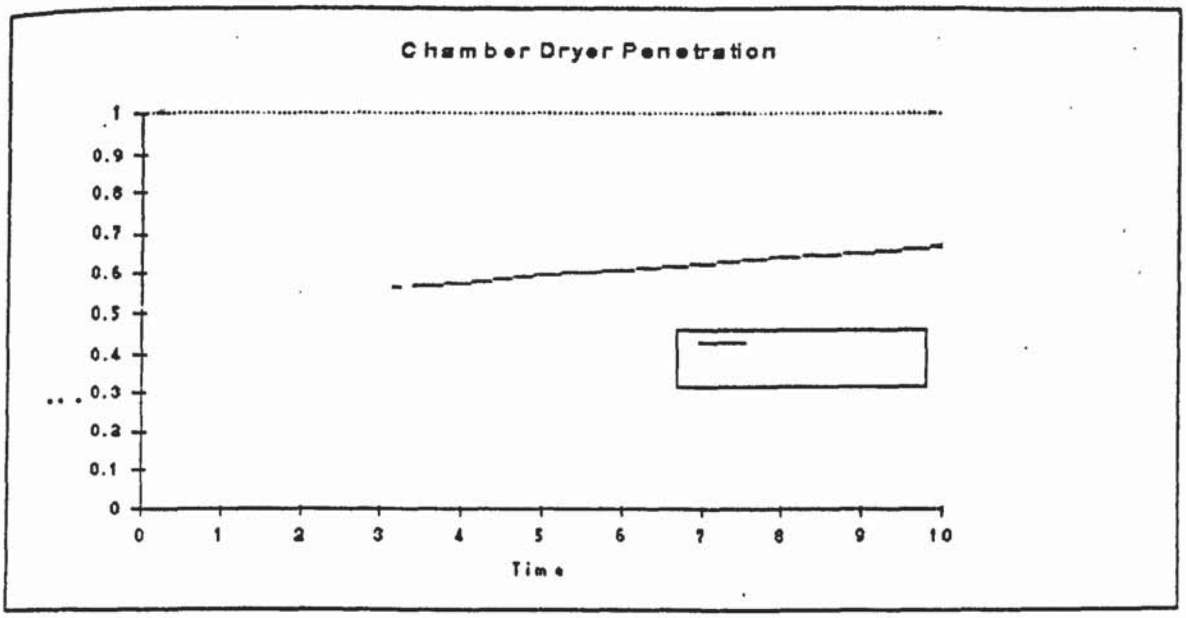
Chamber Drying Demand Profile
30
25
20
15
10
5
0
10.0
8.0
6.0
4.0
2.0
0.0
00:00
01:30
03:00
04:30
06:00
07:30
09:00
10:30
12:00
13:30
15:00
16:30
18:00
19:30
21:00
22:30
Time
kW Demand
% Site Demand
DSM Options
Profile Details
Chamber Dryer In-Situ
View
Return to Process
Exit

Chamber Drying DSM Options

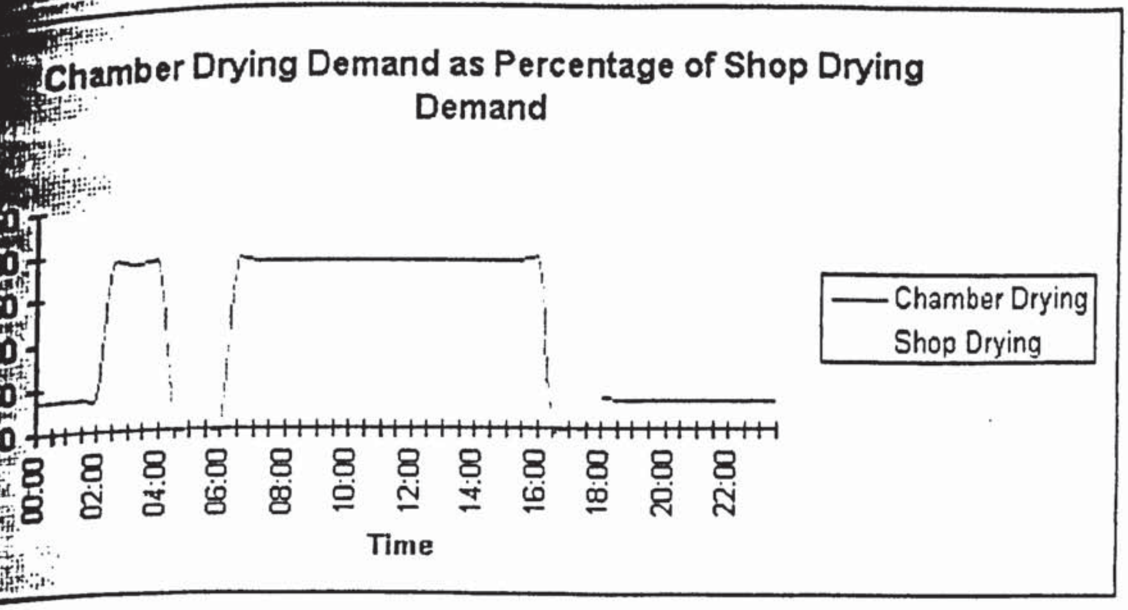
	Applicable Technologies	*Application Area*	*Practicality*
Load Reduction	HEMs, VSDs.	Fan Drives.	Negligible. Size of motors (1-4 kW) negates use of VSDs. HEM installation achieves 2-5% reduction in kW.
Peak Lopping	VSDs.	Fan Drives	Negligible. Restricted by motor size (above).
Load Shifting	Timer Controls.	Process Control	Long cycle times (10hrs +) lend process to off-peak utilisation.
Dynamic Load Shaping			
Load Growth	MW & RF	Dryer Units	Drying considered bottle-neck in production process. Therefore potential to increase production and electrical demand/consumption through shorter drying cycles

Exit

Double-Click Icon to Access Data



Exit



Example Profile

Return to Shop Drying

APPENDIX C

DSM MARKET SEGMENTATION SOFTWARE

This appendix provides the questionnaire that was utilised in the market survey to form data for the cluster analysis procedure. The respondents are asked to rate the importance of variables which, by prior hypothesis, are deemed to influence the decision by a company to invest in energy efficiency measures. The clustering algorithm utilised and further details on cluster analysis are provided in Chapter 11.

The following questionnaire has been designed to provide information to allow an assessment of the varying attitudes towards investment in energy efficiency that exist within the industrial sector. The results of a statistical procedure applied to the questionnaire responses will enable Regional Electricity Companies (RECs) to develop a greater understanding of the energy needs of their customers. This will ultimately enable the RECs to devise the most suitable energy services package for a particular customer, helping to reduce energy costs and possibly deliver improvements in productivity and quality.

All questionnaire responses will be treated as **strictly confidential** and will not be made available to any person other than the originator of the project. A report on the project findings will be made available free of charge to any respondent who wishes to receive one.

These questions are designed to look beyond the traditional explanations of investment in energy efficiency, such as electricity intensity, and into the area of organisational behaviour in terms of cost control, investment appraisal, and attitudes towards and perceptions of energy efficiency. It is intended that the questionnaire will allow those customers which would be more likely to participate in DSM and energy services to be identified.

Please consider the following business/energy related statements and mark them in accordance with how strongly you agree/disagree in accordance with the scale:

Strongly Agree	Slightly Agree	Neutral	Slightly Disagree	Strongly Disagree
5	4	3	2	1

1/ Investment in innovative technology is a fundamental aspect of your company's strategy 5 4 3 2 1

2/ Energy cost control receives investment status on equal terms with other areas of cost control 5 4 3 2 1

3/ Investment in energy efficiency is treated on equal terms with other areas of investment 5 4 3 2 1

4/ All production plant technologies are subjected to pro-active maintenance 5 4 3 2 1

5/ All non-production technologies are subjected to pro-active maintenance 5 4 3 2 1

6/ Investment decisions made at local cost centres i.e. departmental manager level 5 4 3 2 1

7/ Investment decisions made by central office 5 4 3 2 1

8/ Investment in energy efficiency is justified (financially) by Payback Period over Net Present Value calculation 5 4 3 2 1

9/ Essential to own, not lease, production process equipment 5 4 3 2 1

10/ Essential to own, not lease, site services equipment such as Lighting, Compressors, HVAC 5 4 3 2 1

11/ The development of innovative products is important to your company's strategic outlook 5 4 3 2 1

12/ Capital expenditure for energy efficiency investment could be readily made available if favourable projects were identified 5 4 3 2 1

13/ Energy saving projects seen as low risk 5 4 3 2 1

14/ A close working relationship with your energy suppliers is seen as very important 5 4 3 2 1

15/ Your company strives to compete on product quality before product price 5 4 3 2 1

16/ Active membership of trade organisations is very important to the company 5 4 3 2 1

17/ Energy saving projects are seen as relatively low risk when compared with other investments 5 4 3 2 1

18/ What rate of annual rise in electricity costs would prompt your company to actively seek out energy efficiency measures (please circle):

5% 10% 15% 20% >20%

19/ What rate of return would your company usually assign to projects deemed as:

High risk ....% Medium Risk ....% Low Risk ....%

Has your Company invested in any of the following areas in the past ten years, please state either YES/NO:

i/ Good Housekeeping - Investment at very low cost, usually part of good maintenance e.g. installation/upgrade of lagging, insulation, double glazing, zone steam control etc. ....YES/NO

ii/ Plant Modifications - Capital expenditure on equipment to reduce energy consumption of existing process/services equipment e.g. High efficiency motors/lighting, power factor correction, heat recovery etc..........YES/NO

iii/ Organisational Changes - changes in operations in order to increase energy efficiency e.g. appointment of an energy monitor, modified working hours, process use scheduling etc..........YES/NO

iv/ Improved Technology - significant capital expenditure for the primary purpose of process/production benefits which has also delivered reduced energy costs e.g. innovative process techniques.........YES/NO

v/ Monitoring and Targeting - the setting of specific energy consumption levels for a specific volume of production.........YES/NO

20/ Is your company

- **a/ Proprietor owned** ☐
- **b/ Non-diversified UK group** ☐
- **c/ Non-diversified Foreign group** ☐
- **d/ Diversified UK group** ☐
- **e/Diversified Foreign group** ☐