The Impact of Electricity as a Source of Energy

"A Demand Side Management Perspective"

"Dissertation Submitted to the University of Kwa-Zulu Natal in Partial Fulfilment of the Requirements for the Degree in Masters of Commerce"

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Declaration

I, **Nalandran Chetty**, declare that this master's project is my own, unaided work, except as indicated in the acknowledgements, the text and the references. It is hereby submitted in partial fulfilment of the requirements for the degree in Masters of Commerce at the University of Kwa-Zulu Natal.

Signature:

Date: November 2005

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Abstract

The essence of this dissertation is to enlighten the client on those strategic options available for a financially viable energy source and is also aimed at increasing the electricity share of the energy market, which is currently approximately 25%. This dissertation focuses on the industrial sector of the economy.

Energy sources available to the Industrial sector, namely coal, diesel, illuminating paraffin, heavy fuel oil, liquefied petroleum gas and electricity, were selected for this specific study and compared in eight geographic areas. These inland areas include Pretoria-Witwatersrand-Vereeniging (PWV), Bloemfontein, Pietersburg and Nelspruit, and the coastal areas include Cape Town, Durban, Port Elizabeth and Richards Bay.

As the energy cost is not the only factor influencing the total cost of using a particular energy source, the objective for this study was also to evaluate energy sources on an effective cost basis, taking account of energy price as well as indirect costs and utilization efficiencies. The typical industrial application of steam generation was selected and the costs related to using various energy sources in this application evaluated.

This study also considers critical factors likely to be taken into account by consumers when choosing an energy source, or deciding on an energy conversion, which includes Demand Side Management (DSM). DSM refers to a process by which electric utilities especially Eskom, in collaboration with consumers achieve predictable and sustainable changes in electricity demand. These changes are affected through a permanent reduction in demand levels (Energy efficiency) as well as time related reduction in demand level (Load Management)

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LIST OF ABBREVIATIONS	
Btu	British Thermal Unit
C/Kg	Cents per Kilogram
CFE	Commission Federal de Electricidad
CFL	Compact Flourescent Lamp
C/kWh	Cents per Kilowatt Hour
C/l	Cents per Litre
C/MJ	Cents per Megajoule
CNFL	The National Company for Power & Light in Costa Rica
CPI	Consumer Price Index
CV	Calorific Value
DME	Department of Mineral and Energy
DSM	Demand Side Management
EE	Energy Efficiency
EROI	Energy Return on Investment
ESCO	Energy Services Company
GAO	Government Accounting Office
GDP	Gross Domestic Product
GEF	Government Energy Fund
GNP	Gross National Product
GWh	Gigawatt Hour
HFO	Heavy Furnace Oil
HV	High Voltage
IBLC	In Bond landed Cost
IP	Illuminating Paraffin
Kg	Kilogram
kV	Kilo Volt
kW	Kilowatt
kVA	Kilo Volt Amp
kWh	Kilowatt Hour
LPG	Liquefied Petroleum Gas
LTD	Limited
LV	Low Voltage
MJ	Mega Joule
MVA	Mega Volt Amp
MW	Mega Watt
NMD	Notified Maximum Demand
NER	National Electricity Regulator
PELP	Poland Efficient Light Project
PF	Power Factor Correction
PTY	Proprietary
PWV	Pretoria - Witwatersrand - Vereeniging
RES	Reference Energy System
SEJ	Solar Emojoules
R/t	Rand per Ton
RES	Reference Energy System
UNDP	World Bank, Energy Sector Management Assistance Program
UTE	Utility in Uruguay

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CHAPTER 1

OVERVIEW OF STUDY

10. INTRODUCTON

The student has been employed in the private sector for thirteen years and has a passion for engineering, prior to joining Eskom in 1997. Currently, the student is an Advisor to the industrial sector employed by Industrelek, which is a subsidiary to Eskom, a South African Electricity Utility, initiated this study using the application of systems thinking. The essence of this dissertation is to enlighten the client on those strategic options available for a financially viable technology solution, therefore encourage the use of electricity in South Africa and thereby to grow the electricity share of the total energy market.

Currently about 25% of the energy market in South Africa is in the form of electricity, of which Eskom supplies 98%. The potential for increasing this market share is determined by techno-economic factors influencing customer choice of technology, such as the viability of utilising electricity rather than alternative energy sources in new applications, and the potential for switching from coal, petroleum and other energy sources to electricity in the case of existing applications.

Relative energy prices, utilisation efficiencies, capital cost of conversion equipment and indirect cost-savings need to be considered, even the possibility of co-generation potential in applications where by-products could possibly be used to generate electricity (Owen 1970).

This study premise is that consumers have a choice of several competitive energy sources for various technology applications, and that the decision to utilise a particular technology or combination is dependent on several critical factors, (Kaufman 1994). However, price alone does not necessarily give a true indication of the actual energy cost in a particular application and an equitable basis for price and cost comparisons is required.

In addition, an analysis of fixed and variable costs associated with using various energy sources and associated equipment for steam production will be undertaken in order to gain a better understanding of the total cost of using these energy sources as opposed to comparing costs on a simple energy equitable basis. Different industrial boilers (coal, gas, liquid fuel and electric) will be appraised in terms of cost, efficiency, ratings, power factor correction, demand side management and various other factors. The results will be calculated in terms of cost per unit of steam produced.

Several metro electricity tariffs are compared and it is established that these prices, on average, are substantially higher than Eskom prices for similar industrial load-patterns. Diesel is the most expensive energy source in all areas studied except Port Elizabeth, where LPG is the most expensive. Relative prices for November 2004, with electricity = 100 in the PWV area are summarised below for comparative purposes:

Table 1.1: Relative energy prices

Relative energy prices (Eskom electricity = 100 in PWV)

Energy source	PWV	Durban	Port Elizabeth	Cape Town
Coal	16	24	34	34
Eskom electricity	100	101	102	103
HFO	102	89	89	89
Coal gas	134	134	N/A.	N/A.
Metro electricity	149	138	147	141
IP	167	155	155	155
Diesel	213	205	205	205
LPG (bulk)	286	258	300	259

(Continued)	Bloemfontein	Nelspruit	Pietersburg	Richards Bay
Coal	22	20	20	20
Eskom electricity	101	101	101	101
HFO	105	105	108	89
Coal gas	N/A.	N/A.	N/A.	134
Metro electricity	149	191	187	126

IP	168	168	171	159
Diesel	214	214	217	210
LPG (bulk)	286	291	291	282

Source: Municipalities, ***Mcphail & Cullen Coal, Dept of Mineral & Energy***

In terms of energy price trends over the past 6 years, it was found that the average price increase for Eskom electricity was lower than for all other energy sources and less than the average inflation rate of 4.8%/yr. Results for the inland area are summarised below:

Table 1.2: Average price increase

Energy source	**Average price increase for 1998 - 2004 (%/yr)**	
	Nominal	**Real**
Eskom electricity	**4.8**	-2.0
Coal	11.9	5.1
LPG	13.2	6.4
Diesel	13.9	7.1
Illuminating paraffin	18.9	12.1
HFO	19.3	12.5
Coal gas	23.0	16.2

Source: Municipalities, ***Mcphail & Cullen Coal, Dept of Mineral & Energy***

The trend analysis indicated that the relative increase in Eskom electricity prices, averaged over the past 6 years, was significantly lower than that of all other energy sources, resulting in these fuels becoming less-and-less price-competitive. The hefty petroleum fuel price hikes during the year 2002 have, as a result of escalating crude oil prices and a weakening Rand, contributed significantly to the current situation (Becker 1983). This dissertation considers critical factors likely to be taken into account by consumers when choosing an energy source, or deciding on a technology conversion. These include criteria such as availability of appropriate technology, cost-benefits and quality of supply. Price elasticity of energy demand is discussed. Elasticity of several petroleum fuels was evaluated, and it is suggested that energy demand is generally price-inelastic. If alternative energy sources are readily available at lower cost, however, energy switching is likely to occur in the longer term.

1.2 INDUSTRELEK'S HISTORY

Market conditions and Eskom's excess electricity capacity dictated that Eskom focus on the different sectors within its total market. Among these sectors were agricultural, residential, commercial and the industrial market. The industrial market, due to its sales potential, size and specific individual needs justified Eskom's creation of a specialised branded service called Industrelek.

The branded service was established in May 1993. It was a service, which was offered to the various sectors in the industrial market using technically qualified sales personnel throughout South Africa. In 1997 Industrelek became an advisory service, which could analyse your energy needs, do feasibility studies and cost comparisons. The aim was to recommend solutions to increase productivity, product quality and inevitably profitability.

In 1998, a new service approach was taken. The brand was no longer known as an advisory service for industry but became focussed on world class energy solutions for industry. Industrelek became the provider of information on a company's total energy requirements.

1.3 THE INDUSTRELEK TEAM

A team of approximately 60 sales consultants aims to assist manufacturers to improve their plant efficiency. Technically qualified consultants operate throughout the country with the majority located close to large industrial manufacturing areas. Industrelek competes in the energy market and therefore all other forms of energy are seen as competition. Industrelek is cognisant that often the biggest cost variable in a manufacturing concern is the energy cost.

Therefore, the student believes that the modern manufacturer needs to be exposed to the benefits and critical success factors involved in the various technologies available to him.

1.4 INDUSTRELEK'S SERVICE

Often industrial customers with a specific problem will approach Industrelek and initiate a joint project in an effort to establish a solution to a problem. Institutes and associations, some of which have Industrelek as council members, support Industrelek in locating appropriate energy and technology-related solutions. Here are some off the services offered by Industrelek:

- Total energy analysis to identify areas of wastage and improvement
- Recommendations on process and technology improvements
- Compile comparative costs of alternative energy sources
- Assessment studies to determine current and future needs
- Introduce reliable and reputable suppliers of electrical technologies.
- Advice on the most appropriate energy source – even if it means a source other than electricity.
- Power factor correction
- **Demand side management (DSM)**

1.5 PROBLEM DEFINITION

Inca Lime based in Dendron, is situated in Northern Province, produces a non-metallic substance called Flourspar, which is used in the production of Hydro Flouric Acid. This commodity produced by Inca Lime is predominantly for the export market. Inca Lime utilizes steam for the curing and drying process, which is generated by coal fired boilers. Coal as an energy source is polluting the product. Inca Lime will lose the contract if the problem is not rectified.

A meeting was scheduled with the directors of Inca Lime and the student. Inca Lime ensured that the student received cognisance that they were willing to relocate the plant in order to switch to an energy source and technology provided it is financially viable. Therefore, the student decided that a feasibility study of an alternate energy source, which incorporate energy price trends, comparisons, power factor correction, demand side management and steam costs for different boilers would be the way forward.

Demand Side Management (DSM) activities involve a range of load management initiatives that focuses on the reduction of electricity during peak periods. Energy efficiency is one of the measures that fall under the umbrella of DSM. However, due to additional societal and environmental benefits of energy efficiency and the emphasis of Government on EE, The National Electricity Regulator (NER) has referred to energy efficiency as a measure alongside DSM load management measures. Therefore DSM refers to all energy efficiency and load management activities that reduce peak electricity demand.

The NER is mandated to ensure that there is sufficient installed generation capacity to meet the requirements of future electricity demand. The forecasted demand indicates that their will categorically be a need for new generation plants. Commissioning of new peak generation is inevitable.

However, in order to maintain a safe supply demand situation (acceptable reserve margins), provide energy services at least-cost to all customers, improve on end-user energy efficiency and enforce government's objectives on energy efficiency in the electricity sector. Therefore DSM programmes must be successfully implemented.

Problems are as follows:

- The current installed peak generating capacity (while maintaining a safe reserve margin) is insufficient to meet forecasted peak load. This implies that a new peaking generating capacity would have to be commissioned sooner in order to ensure that there is sufficient peaking generation to meet the demand.

- Additionally, South Africa is characterised by inefficient end-use of electricity in all consumer classes. This has compounded the requirement for new peak generation capacity as indicated by Load Forecast.
- Under restructuring there is no guarantee that electricity suppliers would implement energy efficiency programmes or end-users would engage in these activities through market signals
- Inefficient use of electricity has severe environmental impacts and negative health effects.
- There are insufficient regulatory mechanisms within national policy framework to ensure adequate implementation of DSM programmes.

1.6 OBJECTIVES OF STUDY

The main objectives are to:

- Establish comparative prices of selected energy sources
- Evaluate the effect of energy price on market share
- Identify critical factors likely to influence customer choice
- Establish pricing structures of energy sources available to the industrial sector
- Determine steam cost costs for different boilers
- Analyse the Demand Side Management options available

In order to ensure meaningful results, energy prices for a given sector are compared in relatively small geographic areas rather than by using aggregated national or provincial data, which are usually, weighted averages for a wide range of prices, dependent on grades and transport costs.

1.7 SCOPE AND LIMITATIONS

Subsequent to deliberations with DME it was decided to limit the scope of this study as follows:

Energy source: Coal, coal gas, diesel, illuminating paraffin, heavy fuel oil, liquefied petroleum gas and electricity

Sector: General industry

Energy prices: Comparisons and trends in nominal rand

Time period: 1995 - 2005

Geographic areas: Coastal areas – Cape Town, Port Elizabeth, Durban
Inland areas – Bloemfontein, Pietersburg, Nelspruit
Pretoria-Witwatersrand-Vereeniging (PWV).

1.8 STRUCTURE OF STUDY

The remainder of this dissertation will be structured as follows:

Chapter 2

Providing an evaluation of net energy, energy system engineering and aggregation which seeks to compare the amount of energy delivered to society by a technology to the total energy required to find, extract, process, deliver, and upgrade that energy to a socially useful source. In this chapter the principles and theories will be reviewed and argued.

Chapter 3

Deliberating the pricing structures of energy sources available to the industrial sector, namely coal, diesel, illuminating paraffin (IP), heavy fuel oil (HFO), liquefied petroleum gas (LPG) and electricity.

Chapter 4

This study will be undertaken to compare the latest available energy prices in South Africa and to determine steam costs related to using various energy sources. Energy sources available to the Industries sector, namely coal, coal gas, diesel, illuminating paraffin, heavy fuel oil, liquefied petroleum gas and electricity, will be compared in eight geographic areas.

Chapter 5

This study will analyse and evaluate the DSM process, whereby an electricity supplier influences the way electricity is consumed by the customer; in terms of planning, implementation and monitoring of the end-user's activities designed to encourage the consumer to modify his pattern of electricity utilization. This will include timing and level of electricity demand.

Chapter 6

Deals with the reflection, conclusion and generation of various options

Chapter 7

Outlines the implementation plan.

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CHAPTER 2

EVALUATION, AGGREGATION AND DSM OF ENERGY

2.1 INTRODUCTION

One technique for evaluating energy is net energy analysis, which seeks to compare the amount of energy delivered to society by a technology to the total energy required to find, extract, process, deliver, and otherwise upgrade that energy to a socially useful form. Energy return on investment (EROI) is the ratio of energy delivered to energy costs (Cleveland *et al.*1984; Hall *et al.*1986; Gever *et al.*1986). Biophysical and ecological economists argue that net energy analysis has several advantages over standard economic analysis (Gilliland 1975; Hall *et al.*1986). The authors review the principal assumptions and methods for aggregating energy flows: the basic heat equivalents approach, economic approaches using prices for aggregation, emergy analysis, and thermodynamic approaches such as exergy. They argue that economic approaches such as the index or marginal product method are superior because they account for differences in quality among fuels.

2.2 MARKET STRUCTURE AND PRICING

US Electricity and Natural Gas retail market have developed into two different market structures. In some jurisdictions, a dual-product monopolist supplies both electricity and natural gas, while in others, two single product monopolists separately offer electricity and natural gas.

The political economy literature suggests that prices may differ in the absence of demand and cost differences. This work, beginning with (Stigler 1971) and (Peltzman 1976) argues that the regulated price will reflect the regulator's preferential weights assigned to specific consumer groups. Furthermore, (Becker 1983) suggest that lobbying activity among consumer groups, which is a source of the regulators' preferences, will be proportional to the exceed gains from lobbying and inversely proportional to the costs of lobbying.

2.2.1 Interest Groups

(Stigler 1971) and (Peltzman 1976) argue that the prices will reflect the relative weights regulatory agencies place on the consumer surplus of their constituents. In addition, they argue that we would expect the regulators' weight to be positively correlated with the efficacy of the different consumer classes. For example, given that industrial consumers are more concentrated, we would expect industrial consumers to have higher weights, relative to residential consumers, who are more, dispersed. This will lead to lower rate for industrial consumers.

(Becker 1983) provides a formal analysis of interest group activity, focusing on the tax policy; however, his results are also applicable to regulatory pricing. Becker finds that relative taxes will depend on the political efficacy of the interest group, as well as the dead-weight loss of taxation associated with each interest group. Therefore, we would expect organizations with more elastic demand to face lower regulated prices, since the dead-weight loss from price increases is proportional to the electricity of demand.

2.2.2 Alternative Sources

The proposition that regulators respond to interest group pressure almost surely implies that regulators will also respond to lobbying activities of the utilities that they oversee. In fact, the issue of relative pricing of single and dual-product electricity organizations was first analyzed by (Owen 1970) and (Landon 1973) as a test whether regulators respond to increased market power of dual-product organizations. (Owen 1970) estimates a reduced form pricing equation, controlling cost and demand variables.

His results suggest that dual-product organizations have higher electricity prices. Owen interprets these results as evidence of regulatory imperfections, since dual-product organizations will have a grater incentive to price higher than single product organizations. His results were subsequently questioned by (Landon 1973), who included additional cost and demand variables. Landon interprets this as evidence that regulators do not respond to the incentives of the organization.

2.3 ENERGY VERSUS ECONOMIC ANALYSIS

The energy events of the 1970's raised the issue of whether economic measures such as price accurately captured all the relevant features of an energy supply process. Economists generally argue that, by definition, the price of a fuel automatically captures all such relevant features. Yet, a strong case can be made that the standard economic approach to measuring the economic usefulness of a fuel yields one type of information and only partially informs us about all relevant aspects of resource quality.

Net energy analysis, through the calculation of EROI, informs us about some of those other qualities, such as the potential for a fuel source to yield useful energy to the rest of the economy. Such qualities may or may not be reflected in a fuel's price. As (Peet *et al.* 1987: 240) stated:

"We believe the conventional economic perception of the 'value' of primary energy resources is incomplete and potentially misleading, in that it does not adequately take account of the factors which constrain a society's ability to obtain useful consumer energy from such sources".

Many unsubstantiated claims were made about the net energy analysis enjoyed from many of the problems facing economic analysis, making it a superior decision-making tool (Gilliland, 1975). Some energy analysts proposed a theory of economic and social value based on energy (Odum, 1971, 1977; Hannon, 1973; Costanza, 1980, 1981) which economists were quick to criticize.

2.3.1 Energy Analysis and Policymaking

Net energy analysts promote their discipline using a range of arguments. (Gilliland 1975) argued that compared with economic analysis, net energy analysis of alternative energy technologies could provide more information of a less conflicting nature to policy makers. Similarly, the Government Accounting Office (GAO 1982) argued that the strength of net energy analysis is that it gives policy makers the opportunity to consider the EROI of an energy technology independent of its profit potential and other financial considerations.

(Bullard 1976) made an analogy between net energy analysis and environmental impact statements, arguing that quantitative assessments of the impact of new technologies may provide information to policy makers in the same way the environmental impact statements address external effects, not adequately dealt with in the market. (Chapman *et al.* 1974) cited three reasons why net energy analysis of energy technologies is desirable.

First, the energy processing sectors of most industrial nations use significant portions of total national energy use and therefore offer a significant potential for energy conservation. Second, waste heat production from fossil fuel conversion poses a major hazard to local and global climate. Third, it is essential to know the energy cost of energy itself in order to assess the energy costs of other goods and services.

Energy analysts have argued that inflation, subsidies, regulations, uncertainty about future prices, discount rates and other market imperfections prevent monetary analyses from making consistently accurate assessments of energy technologies (Gilliland 1975; Slesser 1977; Cleveland & Costanza 1984). Energy analysts argue that this quality gives their models a significant advantage over economic analysis in the effort to evaluate future energy supply. As (Slesser 1977: 261) stated:

"Because of a better handle on the future energy requirements for production, as opposed to discounted money costs of production, energy analysis gives a faster signal of impending change. Where energy analysis can be of immense value is in normative forecasting hence its value to technology assessment and demand forecasting."

Many economists have rejected these claims made by energy analysts. For example, critics have rejected (Gilliland's 1975) sweeping claim that the results of net energy analysis do not change when dollar values change due to inflation or changes in the discount rate (Webb & Pearce 1975; Huettner 1976; Allesio 1981). Critics argue that net energy results are sensitive to market circumstances, and therefore subject to change over time just like monetary analysis.

Thus, net energy analysis may not be a better allocator of resources where market imperfections exist. Critic's point out that EROI calculations are market determined to the degree that they depend on the technology, industry structure, discount rate and prices that exist at the time.

Changes in any of those factors will undoubtedly alter the energy costs of goods and thereby alter the results of net energy analysis. As (Huettner 1976: 104) argues:

"A net energy analysis of a specific technology, such as the present nuclear fuel cycle and its supporting techniques, depends on the prices, discount rates, and other market conditions existing at the time it was made. As prices change through time, the energy content of steel, copper, cement, and all other inputs used in the nuclear fuel cycle are likely to change because of substitution effects, even if there is no change in technology and market structure".

2.3.2 Energy Aggregation and Energy Quality

Aggregation of primary level economic data has received substantial attention from economists for a number of reasons. Aggregating the vast number of inputs and outputs in the economy make it easier for analysts to see patterns in the data. Some aggregate quantities are of theoretical interest in macro-economics. Measurement of productivity, for example, requires a method to aggregate goods produced, which have diverse and distinct qualities. For example, the Post-War shift towards a more educated work force and from non-residential structures to producers' durable equipment requires adjustments to methods used to measure labour hours and capital inputs (Jorgenson & Griliches 1967).

Econometric and other forms of **quantitative analysis** may restrict the number of variables that can be considered in a specific application, again requiring aggregation. Many indexes are possible, so economists have focused on the implicit assumptions made by the choice of an index in regards to returns to scale, and other factors. These general considerations also apply to energy. The simplest form of aggregation, assuming that each variable is in the same units, is to add up the individual variables according to their thermal equivalents (BTUs, joules etc.). Equation 1 illustrates this approach:
E t □̣E it
i =1
N
□̣(1)

where E represents the thermal equivalent of fuel i at time t. The advantage of the thermal equivalent approach is that it uses a simple and well-defined accounting system based on the conservation of energy, and the fact that thermal equivalents are easily and uncontroversially measured. This approach underlies most methods of energy aggregation in economics and ecology, (Odum 1957), national energy accounting (USDOE 1997), energy input-output modeling in economies (Bullard *et al*. 1978) and ecosystems (Hannon 1973), most analyses of the energy/GDP relationship (e.g. Kraft & Kraft 1978) and energy efficiency, and most net energy analyses (Chambers *et al*. 1979).

Despite its widespread use, aggregating different energy types by their heat units embodies a serious flaw: it ignores qualitative differences among energy vectors. They define energy quality as the relative economic usefulness per heat equivalent unit of different fuels and electricity. (Schurrand Netschert 1960) was among the first to recognize the economic importance of energy quality. Noting that the composition of energy use changes significantly over time, Schuss and Netschert argue that the general shift to higher quality fuels affects how much energy is required to produce GNP.

The quality of electricity has received considerable attention in terms of its effect on the productivity of labour, capital and on the quantity of energy required to produce a unit of GDP (Schurr & Netschert 1960; Jorgenson 1986; Devine 1986; Rosenberg 1998). Less attention has been paid to the quality of other fuels, and few studies use a quality-weighting scheme in empirical analysis of energy use. The concept of energy quality needs to be distinguished from that of resource quality (Hall *et al*. 1986). Petroleum and coal deposits may be identified, as high quality energy sources because they provide a very high-energy surplus relative to the amount of energy required to extract the fuel. On the other hand, some forms of solar electricity may be characterized as a low quality source because they have a lower energy return on investment (EROI).

2.3.3 Economic Approaches to Energy Quality

The heat equivalent of a fuel is just one of the attributes of the fuel and ignores the context in which the fuel is used, and thus cannot explain, for example, why a thermal equivalent of oil is more useful in many tasks than is a heat equivalent of coal (Adams & Miovic 1968; Mitchell 1974; Webb & Pearce 1975). In addition to attributes of the fuel, marginal product also depends on the state of technology, the level of other inputs, and other factors. According to neoclassical theory, the price per heat equivalent of fuel should equal its value marginal product and therefore, represent its economic usefulness. In theory, the market price of a fuel reflects the myriad factors that determine the economic usefulness of a fuel from the perspective of the end-user. Consistent with this perspective, the price per heat equivalent of fuel varies substantially among fuel types. The different prices demonstrate that end-users are concerned with attributes other than heat content. As (Berndt 1978: 242) states:

> *"Because of variation in attributes among energy types, the various fuels and electricity are less than perfectly substitutable - either in production or consumption. For example, from the point of view of the end-user, a Btu of coal is not perfectly substitutable with a Btu of electricity; since the electricity is cleaner, lighter, and of higher quality, most end-users are willing to pay a premium price per Btu of electricity. However, coal and electricity are substitutable to a limited extent, if the premium price for electricity were too high, a substantial number of industrial users might switch to coal. Alternatively, if only heat content mattered and if all energy types were then perfectly substitutable, the market would tend to price all energy types at the same price per Btu"*

Do market signals (i.e. prices) accurately reflect the marginal product of inputs? (Kaufmann 1994) investigates this question in an empirical analysis of the relation between relative marginal product and price in US energy markets. He estimates a reduced form of a production function that represents how the fraction of total energy use from coal, oil, natural gas, and primary electricity (electricity from hydro and nuclear sources) affects the quantity of energy required to produce a given level of output .The partial derivatives of the production function with respect to each of the fuels gives the marginal product of individual fuels, in which marginal product is defined as the change in economic output given a change in the use of a heat unit of an individual fuel.

The results indicate that there is a long run relation between relative marginal product and relative price and that several years of adjustment are needed to bring this relation into equilibrium. The results propose that over time prices do reflect the marginal product - and hence the economic usefulness - of fuels.

Other analysts calculate the average product of fuels, which is a close proxy for marginal products. (Adams & Miovic 1968) estimate a pooled annual cross-sectional regression model of industrial output as a function of fuel use in seven European economies from 1950 to 1962. Their results indicate that petroleum is 1.6 to 2.7 times more productive than coal in producing industrial output. Electricity is 2.7 to 14.3 times more productive than coal. Using a regression model of the energy/GDP ratio in the U.S., (Cleveland *et al* 1984) find that the quality factors of petroleum and electricity relative to coal were 1.9 and 18.3, respectively.

2.4 DESIGN OF ENERGY SYSTEM

The 1973 oil price shock increased public interest in ways to reduce the need for imported oil by introducing locally refined energy and by energy conservation. When oil prices sank in 1987, the increasing concern for the environment and the emerging issue of climate change maintained the public interest.

Although the example of the Swedish support for development of energy efficient stoves shows that the idea of balancing energy supply and demand by means of energy efficiency measures dates back to 1973. From the very beginning the balance between energy supply and demand could be addressed by applying and modifying advanced mathematical models that had been developed since 1957 for designing the energy supply system (Turvey & Andersson 1977), e.g. linear programming and dynamic programming.

2.4.1 Classical Energy Systems Engineering

In the American work "A Time to Choose" (Freeman *et al.* 1974) presented the benefit of a joint optimisation of energy supply and energy demand. The study showed that, by primarily improving the demand-side energy efficiency it is possible to reduce the annual increase in energy use to zero. In the United Kingdom, (Leach *et al.* 1979) prognosticated the future need for primary energy in the UK by forecasting the need for useful energy and the demand-side efficiency. They demonstrated that it was likely that the energy demand would start to decrease as from 1990. The idea that improved demand-side energy efficiency may work as a new energy source was thoroughly applied by (Meyer-Abich & von Weizsäcker 1979). They argued that, compared to energy supply solutions, improved demand-side energy efficiency had many advantages for addressing various energy issues, e.g., reducing the cost for energy supply, decreasing pollution of the environment, ensuring the energy supply.

In conjunction with the preparation of "A Time to Choose," a formal description of the energy system was developed at the Brookhaven National Laboratory in the U.S. This description is called the reference energy system (RES) (Marcuse *et al.* 1976). In short, it is a graphic model that describes all relevant energy flows and energy conversions in an energy system.

The RES is well suited for transformation into mathematical models that can be used for determining the efficient balance between energy supply and end-use measures e.g. energy conservation. (Hoffman 1974), (Finon 1974), and (Marcuse *et al.* 1976) described early RES-based models. The models provide insight about: new technology, structural changes, fuel mix, emissions and energy conservation.

(Marcuse *et al* 1976) differentiates between two types of dynamics: intra-period and inter-period. Intra-period dynamics covers aspects that occur within a sub-period of the studied period. The annual load curve is one example. Inter-period includes dynamic aspects that occur during the entire studied period, which may be e.g. 40 years. An example of an inter-period dynamics is increased energy prices. As intra-period dynamics is inherent in the load curve methodologies, the RES methodology can apply theories and methodologies that are developed within the load curve tradition. The planning horizon is usually several decades. Thus, the cost of capital is of vital importance, and appropriate economic methods and theories must be incorporated into the model.

2.4.2 Works Advocating Energy Efficiency

Methods based on the reference energy system emphasise the balance between energy conversion and energy efficiency measures. This balance depends on various factors in the environment of the energy system, such as energy prices, emission constraints, and energy performance characteristics of future energy equipment. Several studies apply a more detailed focus in investigating energy efficiency than the focus usually applied by studies based on the reference energy system.

These "energy efficiency-advocating" works show a large potential for energy savings and argue that utilisation of that potential will substantially decrease the total energy cost without decreasing the utility gained from the energy system. A prominent representative of this opinion is Amory Lovins, who argues that it is possible to decrease the U.S. electricity demand by 75% and the oil demand by 80% without increasing the cost of energy supply and conversion (Lovins 1990).

In Sweden, (Steen *et al.* 1982) and (Bodlund *et al.* 1989) demonstrate the effect on the energy supply system if society were to choose to apply more energy efficient technology than used today. Steen *et al.* writes that it is possible to increase the consumption of useful energy by 50% at the same time as the energy supply demand decreases by 50%. Bodlund *et al.* suggest that, by applying advanced demand-side energy equipment, it is possible both to phase out the Swedish nuclear power plants and to keep an almost non carbon dioxide emitting power producing system.

In "Energy for a Sustainable World" (Goldemberg *et al.* 1988), the scope used by Steen *et al.* and Bodlund *et al.* is widened to concern the entire planet rather than only one nation. They find that it is possible to design the energy system in such a way that it contributes to the solution of other major global problems, e.g. poverty, environmental degradation, and climate change.

The design of such energy systems is made possible by shifting the focus from energy supply to the end use of energy: by paying much more attention to the present and future useful energy demand and the alternative technological options for providing the useful energy needed. They suggest that it is possible by improving the energy efficiency to provide useful energy to a future world in which the population is doubled and a standard of living is much higher than today at the same time as the total energy use increases only by 10%.

2.4.3 Examples of Public Policy Works Considering Energy Efficiency

The scientific work referred to above has had great influence on public policy making. For example, in Sweden, two bills to Parliament (the Swedish Government, 1975 1977) introduce a systems view of energy supply and conservation. In the first bill, energy efficiency is pointed out as one of four cornerstones for adapting the Swedish energy system to increased oil prices. (The other three were oil reduction, investment in new nuclear power and hydropower plants, and international co-operation.)

It was suggested that the annual increase in energy demand should be reduced from 4.5% to 2%. In the second bill to the Parliament (1977), the energy conservation objective was given a concrete form. A reduction in the need for imported energy by means of large investments in energy efficiency measures in buildings was recommended. These investments were estimated to cost between 31 and 48 billion Swedish crowns during the following ten years. The improved energy efficiency was suggested to be facilitated by subsidies, advisory service, and legislation.

In "Our Common Future" (World Commission on Environment and Development, 1987) the perspective is global rather than national. The authors note the energy needed for increasing the standard of living in developing countries, and asks whether it is possible to satisfy that need by energy supply measures only. They present two scenarios: high energy and low energy. The main difference between the two is that the low energy scenario assumes better energy efficient performance characteristics than the high-energy scenario. In the low energy scenario, it is assumed that the energy use per capita in industrialised countries decreases by 50% while that of the developing countries increases by 30%.

Relative 1980, the global energy demand predicted by the high energy scenario increases 2.5 times, while that of the low energy scenario increases only 1.1 times. One conclusion drawn in the study is if the energy use increases according to the high-energy scenario, it seems impossible to create sustainable world development. Consequently, improved energy efficiency is required for increasing global well being.

At the Earth Summit in Rio de Janeiro (United Nations Conference on Environment and Development, 1992), improved energy efficiency was recommended as one strategy for decreasing the damage caused by energy conversion and use: "The basic and ultimate objective of this programme area is to reduce adverse effects on the atmosphere from the energy sector by promoting policies or programmes, as appropriate, to increase the contribution of environmentally sound and cost-effective energy systems, through less polluting and more efficient energy production, transmission, distribution and use."

These public policy works are influenced by recommendations from energy systems engineering methods. Improved demand-side energy efficiency is considered parallel to energy supply measures. This is a thermodynamic approach. However, recommendations on the design of the energy system should also consider control of the system. This issue is reflected by two energy systems engineering methodologies.

2.4.4 Changing the Energy System

Although the scientific works above often note the need for public policies for promoting energy efficiency (Jochem & Gruber 1990), they do not analyse how control of the energy system can be established. There is, however, one very important exception: the demand-side management methodology, which suggests that the demand side of the energy system shall be controlled by the public energy utilities (Nadel *et al.* 1992).

Demand-side management is based on the regulatory regime in the U.S. The fundamental idea is that the public utility commissioner stimulates the energy utility to promote energy efficiency. The utility is rewarded if it proves that it has improved the demand energy efficiency in its sales area.

(Wene & Rydén, 1988) suggest a different approach. They considered that a local energy system, taken as a whole, has no unique management. The system consists of several subsystems, and these subsystems normally have a well-defined management. They conclude that the true management of the community energy system is the network of organisations in the energy system.

2.4.5 Swedish Studies of Energy Utilities

Demand-side management suggests that public energy utilities are essential actors for promoting energy efficiency. This recommendation is based on the prevailing regulation of the utilities in the U.S., which differs from the Swedish and European approaches for regulating the power market. It is likely that the different regulatory frameworks affect the public utilities' interest in energy efficiency.

In Sweden, four recent works address the issue of energy efficiency and Swedish energy utilities. (Elmberg 1993) describes the energy efficiency activities operated by Göteborg Energi in 1993. (Risling & Steen 1993) deal with the "self-organising energy enterprise" in a broader context: the need for improved market orientation for coping with a de-regulated energy market and for vitalising the organisation. The introduction of such energy service products like energy efficiency activities is one strategy for market orientation. They write that an insufficient improvement of the internal organisations hamper the introduction of energy-efficient solutions.

(Olerup 1994) describes the rise and fall of energy efficiency activities at Stockholm Energi. She identifies three phases: monopoly, announced competition, and competition. During these phases, the objective of the energy efficiency activities changes from energy conservation to peak demand conservation and finally, energy sales. The principle forms of the activities changed from "first, visible campaigns aimed at residents; second, invisible audits for professional customers in general; and third, secret contracts with high-voltage customers or big low-voltage customers."

The energy efficiency activities were changed from having a value of their own to becoming downgraded to a side issue to ensure energy sales: " it is now the same person who sells energy and tries to reduce the end users' energy needs. The inherent conflict is no longer decoupled, it is, however, more likely that energy conservation will not survive the competition". Olerup concludes that the energy efficiency activities at Stockholm Energi ceased.

(Höwing & Strid 1995) presented a detailed study of the energy service contract activity at Göteborg Energi. The work is in two parts, the first concerning Göteborg Energi and the second being a market research study of possible improvements of the product. They address the conflict between energy sale and energy efficiency. According to a new formal organisation, the energy sellers shall market the energy service contracts. They write that the sellers' knowledge and experience is in traditional energy sales, and that there is a risk that the marketing of energy service contracts will be given less priority than energy sale. Their suggestion for solving internal competition is to maintain the energy service contracts as an autonomous unit.

2.4.6 Energy Systems engineering called into Question

Although energy systems engineering has gained great influence on the energy utility scene, the approach is still controversial. As demand-side management is the dominant methodology, most critique of energy systems engineering addresses DSM. This debate considers three issues:

- Stepwise refinement of the DSM approach
- Criticism of the fundamental assumptions of DSM
- Responding defence of DSM's assumptions

Measuring energy conservation potentials and energy savings is a key issue in DSM, and an important share of the literature addresses this issue (Proceedings of the 1991 international energy program evaluation conference, 1991) Experiences from various DSM programs are compiled and used for benchmarking among the energy utilities in the U.S (Nadel 1990).

The accuracy of measurements has been criticised (Braithwait & Caves1994) and improvements have been suggested (Vine *et al.* 1994). According to the cost efficiency of the programs, their right to exist has been questioned (Joskow & Marron 1993) and defended (Miller 1994).

In these works, DSM is discussed within its own discipline. The methodology is judged by using estimates and methods developed by the DSM researchers. In addition to the internal evaluations, DSM has been judged according to economic theory. For example, (Ingham *et al.* 1991) shows that the market barriers that justify many DSM programs are limited. (Hasset & Metcalf 1993) write that high discount rates attributed to investments in energy efficiency are neither irrational nor the result of market failure.

(Andersson 1993) states that the search costs imply that the most cost-efficient energy efficient investment will never gain 100% of the market share. (Sutherland 1996) argues against energy conservation programs and writes that they do not reduce the cause of market failures on the energy market, but rather extend regulatory inefficiencies, and the energy conservation literature does not consider the conventional economic measurement of benefits, i.e., the net willingness to pay. He concludes "energy conservation programs rather focus on the market outcome than the market process".

2.5 BOTTOM UP VERSUS TOP DOWN

The debate between proponents of energy engineering and energy economics is discussed in detail by (Hourcade *et al.* 1996) and is referred to below. Energy systems engineering is often seen as bottom-up methods while energy economics is labelled top-down methods (Wilson & Swisher 1993). This label is also used by (Hourcade *et al.* 1996) who discusses the cause for the different estimates of the cost for reducing the greenhouse gases. In this respect, demand-side energy efficiency measures are appointed as an essential strategy for this reduction and almost all of their discussion has to do with energy efficiency.

Energy systems engineers argue that substantial energy efficiency potential exists and, by taking advantage of this potential, the cost of reducing emissions of greenhouse gases is less than that estimated by energy economic analysis. Energy economists, on the other hand, argue that using the energy efficiency potential is either smaller or more costly to utilise than is estimated by energy systems engineering methods.

In short, they focus on three characteristic of the top-down and bottom-up approaches: the purposes of the model, the structure, i.e. the assumptions that are embedded in the model's equation, and finally, external assumptions that are input to the model. Their general conclusion is that "there is no a prior reason that the two modelling approaches must give different results" and continues to argue that it is possible to calibrate top-down models in such way that they match the results of bottom-up models.

They identify three types of purposes: prediction, exploration, and assessment of the feasibility of alternative futures (back casting). Originally, the top-down models had a predictive nature. Bottom-up models were used normatively in back casting studies. Studies that are more recent use scenario techniques for exploring the possible developments of the future.

The top-down models "focus on financial flows across the whole economy" (while sectional models) "focus on the market dynamics". The bottom-up models "focus on the technical margins of freedom likely to be evident at a micro-economic level". In more recent models of both types, their respective weak points have been improved. Furthermore, linked models are developed that incorporate both approaches (Manne & Wene 1992).

The difference between the cost-efficient level of energy efficiency investments recommended by energy system engineering methodologies and the observed investment level in society is often referred to as the "efficiency gap", and the debate between engineers and economists has to do with whether or not this gap exists.

2.6 INTERNATIONAL TECHNOLOGY TRANSFER

International technology transfer is certainly an interdisciplinary subject, and as such it has been written about by scholars and practitioners of economics, political science, management, engineering, industrial relations, international business and finance, law, sociology, and anthropology.

(Reddy & Zhao 1990: 285), in reviewing literature, conclude that "*given the inherent complexity of the subject, findings, conclusions, and contentions of what we know about international technology transfer are fragmented along various specialties*".

Different perspectives of technology transfer stem from different views of technology: as a commodity, as knowledge, and as a socioeconomic process (Rosenberg 1982). The classical economic view of technology is essentially that it is an information-based commodity that can be reproduced without cost and transmitted from one agent to another. In this view, technology transfer is as simple as making a photocopy of design documents or obtaining a working artifact.

In historical development-assistance contexts, technology was often a euphemism for capital, also reflecting this view of technology-as-commodity. But many in the field of technology transfer share the view of technology as knowledge (Krantzberg 1986). This knowledge is brought about through a learning process, and thus technology transfer is fundamentally a process of learning. In this view, transfer of inanimate objects—such as machines and blueprints—by itself does not constitute technology transfer; a view echoed by (Rosenberg & Frischtak 1985)

"instead of being regarded as public information, technology might be more usefully conceptualized as a quantum of knowledge retained by individual teams of specialized personnel. This knowledge, resulting from their accumulated experience in design, production, and investment activities, is mostly tacit, that is, not made explicit in any collection of blueprints and manuals.....each individual firm are a locus where the progressive accumulation of technical knowledge takes place....."

2.6.1 Technological Perspectives

Technological perspectives include the large literature that identifies technical options for reducing greenhouse-gas emissions, which include increasing energy efficiency of existing end uses and of new equipment and processes, increasing energy efficiency of energy production and conversion, expanding the use of renewable energy, switching to less carbon-intensive fuels, and relying more on nuclear power (Watson 1996).

Technologies for improved energy efficiency fall into three major categories:

- ❖ Major industrial-process replacements (usually associated with large industrial restructuring activities),

- Incremental technical improvements or renovations to existing processes and infrastructure, and
- Expanded market supply and demand of higher-efficiency versions of equipment such as industrial boilers, refrigerators, lighting, windows, and motors.

Much of the energy efficiency literature analyzes the technical potential for energy efficiency in different applications and sectors, the technologies needed to achieve that potential, and the costs and economic returns of these technologies (Ficket 1990).

(Ahmed 1994) states that technical-economic potential is analyzed in literature on renewable energy technologies and economics, which exhibits that a wide range of renewable energy technologies are at or near commercially viable stages of development.

(Shove 1995) has challenged the conventional notion that "technical potential" for energy efficiency and greenhouse gas–emission reductions can be separated from the barriers and constraining social and economic factors to technology transfer, and she argues for a more integrated view of "socio-technical potential." Achieving socio-technical potentials does not mean closing an imaginary gap between technical potential and technical reality but rather implies a complex social process of technological change.

2.6.2 Multilateral Agencies with Development Goals

In traditional development assistance, the critical factors for economic growth were seen as capital investment and technology (Riddel 1987). In this development paradigm, technology transfer was very much a transfer of objects, such as power plants and communications infrastructures, selected and specified by donors, that were thought necessary for economic development.

Recently, development assistance has emphasized structural-adjustment policies as preconditions for development lending, and technology transfer has evolved into an instrument by multilateral agencies for achieving desired economic and policy reforms. For example, much development-related technology transfer for higher efficiency of electricity production and use has occurred in the context of electric power–sector reform and restructuring. The World Bank's policies on energy efficiency put technology transfer in the context of encouraging proper economic incentives.

As (Golove 1996) states:

"there is the need to put in place policies, legislation, mechanisms, systems, institutions, and incentives that facilitate technology transfer and encourage the use of the most efficient competitive technologies.....long term potential for major improvements in the conversion of energy into environmentally-benign economic output lies in incentive structures or processes that channel new investment into the most up-to-date and efficient competitive technologies".

2.6.3 Market/Transactions Perspectives

Market/transaction perspectives consider how to achieve sustainable markets for technologies to mitigate climate change and thus harness the power of market-based incentives to accomplish environmental goals. Experience with development assistance for renewable-energy projects in developing countries over the past two decades illustrates the significance of market/transaction perspectives. In the 1970s and 1980s, development assistance agencies attempted to transfer many small-scale renewable-energy technologies such as biogas, cooking stoves, wind turbines, and solar heaters. (Kozloff & Shobowale 1994) confirm that many projects were considered failures because of poor technical performance, lack of attention to user needs and local conditions, and lack of replication of the original projects. Projects emphasized onetime technology demonstrations that failed to comprehend or provide incentive structures, failed to demonstrate institutional and commercial viability, failed to account for continuing maintenance requirements, and failed to generate sustainable markets for the technologies demonstrated.

2.6.4 Market Barriers

Market barriers may prevent seemingly cost-effective energy technologies from diffusing to the extent that their potential and cost effectiveness suggest they will. Market barriers to energy efficiency are well characterized and reflect the existence of viz:

- energy prices that do not reflect true costs
- incomplete information
- externalities
- short time horizons of consumers (coupled with high front-end capital costs)
- limited or "bounded" rationality of consumers
- transaction costs
- imperfect capital markets
- public goods
- institutionally mismatched costs and benefits

The World Bank and the UN argue that technology transfers face these same market barriers. Many studies describe barriers to private-sector technology transfers in terms of the following factors:

- ✓ poor macroeconomic and regulatory conditions
- ✓ weak or distorted demand for environmentally superior technology
- ✓ low technical capability to access, adapt, and develop technology
- ✓ too little information about technological alternatives
- ✓ missing connections between potential partners and the problems of scaling cultural gaps and fostering long-term relationships (Rath & Herbert-Copley 1993).

2.7 DEMAND SIDE MANAGEMENT ON A COMPETITVE MARKET

In April 1994, the California energy regulators published a staff proposal for increasing competition in the old monopoly electricity market in California. In December 1995, the regulators decided to allow all customers to buy power from the power producer of their choice by 2003. This trend of deregulating the electricity market, which also can be observed in Europe, has changed the conditions for demand-side management, i.e. utility-based energy conservation programs.

(Gellings 1996) who originally coined the term demand-side management writes that the future customer strategy of the utilities will have three objectives: to retain existing customers, enhance revenues, and control costs. DSM can play an essential role in obtaining these objectives, but DSM will no longer be the exclusive market focus for the utility industry. He concludes that DSM has been (incorrectly) associated with costly incentives for reducing energy sales and that it is impossible to turn that perception around. Hence, Gellings suggests that it is time to move beyond demand-side management.

(Lovins 1996) gives an optimistic view of energy efficiency activities at utilities. He argues that, in other businesses undergoing deregulation, firms that succeeded appreciated early on that any retail business is a service business. Those who attempted to compete with the pricing only did poorly:

"a strong portfolio of efficiency services would become ***more*** *rather than less important as a core element of utilities' competitive strategy."*

He also foresees a radical change of the electricity business because cheap fuel cells, photovoltaic and other decentralised power generators will put central thermal power stations out of business. This means that, he concludes, the utility of the future is "an energy service company that provides light, comfort and other end-use services, or the means to achieve them, right at your premises."

(Chamberlin & Herman 1996) share the view that energy efficiency will be an important part of energy sales. They note that the 'energy efficiency product' will change from reduced energy need to increased value to customers. The strategy for delivering the energy efficiency product will change from, subsidies to, shared savings and contracts of energy service, but "the market for the energy-related services is clearly large, and this market is clearly integral to the success of the new generation of retail providers". (Nadel & Geller 1996) make a similar prediction and note that the public utilities in U.S. are already rapidly establishing energy service companies as subsidiaries for serving their customers as well as the customers of the competitors.

(Keating 1996) and (Hirst et al. 1996) argue the need for an interim solution for demand-side management. Keating notes that the distribution of electricity will remain a regulated natural monopoly, and he suggests that DSM will continue to have a role driven by service needs (e.g. to help the utility to keep the customer's load), operational needs (e.g. load management), and regulatory needs. Hirst *et al.* (1996) concludes that the utility of the future will be a regulated distribution entity that can be rewarded by the regulators for delivering cost-effective electric energy efficiency improvements.

The character of the DSM programs is likely to change: the participating customers will pay for most of the service they receive, and the service will focus on, the customers' comfort, productivity, and energy cost as well as saving electricity. Many utilities will also use DSM as a marketing tool. This means that, Hirst *et al.* (1996) suggestion for a future role of demand-side management is very close to the current one, although the regulated organisation has been changed from the power producer to the power distributor.

2.7.1 The International Experience of DSM

Since the mid-1980s, US researchers have shown the significance of utility-driven DSM schemes. The Public Utilities Commission in several states of the USA started mandating the utilities to implement DSM schemes. Presently, several utilities in USA, Canada and other countries have accumulated experience of implementing DSM schemes. This sub-section first gives a short introduction to DSM programs in some countries, followed by the larger lessons that may be drawn from the international experience.

Country Experiences

Taking an overview of DSM experiences in many countries is the topic of an independent report. This section draws attention only to selected schemes of some countries in order to highlight certain points.

USA

For over a decade, the regulatory commissions in the USA (called Public Utilities

Commissions) have been directing the utilities to carry out DSM schemes. The commissions also monitor the savings achieved and have directed refinement of DSM plans.

The state of California, USA, has achieved a peak reduction of 4,500 MW to 5,500 MW, which turns out to be 11-14 percent of its peak demand, through utility-sponsored DSM measures. This fairly large saving has been achieved through utility actions in response to the directives of the commissions. During a power crisis around 2001, the voluntary DSM supported by tariff concessions (for reduced consumption) substantially increased the savings to about 6,500 MW. In the absence of such major savings, the energy crisis in California could have been much worse.

Since 1992, US regulatory commissions have been monitoring the peak load reduction and energy saved due to DSM programs initiated by the large power utilities. The US Department of Energy data shows that the USA achieved a reduction of 23,000 MW to 30,000 MW and energy saving of 54,000 million kWh to 60,000 million kWh due to energy efficiency programs initiated by utilities.

This saving does not include the reduction in demand due to the appliance efficiency standards, actions initiated by individual consumer / industry (such as energy audits), the savings due to tighter norms for construction of buildings or the load management programs. Moreover, nearly two-thirds of the peak as well as energy saving came from residential and commercial (non-industry) consumers! (Ref: Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report" December 2003). Report by Prayas Pune (Energy group) for WWF India 15.

Thailand

A DSM project implemented during 1993 to 2000 had a budget of $189 million and had a target of saving 240 MW. Through 19 DSM programs the power utility EGAT achieved a saving of 570 MW at a cost lower than the budget! The cost of saved peak MW was much lower than the cost of supplying additional power! (Ref: “DSM in Thailand: A Case Study” by UNDP, World Bank, Energy Sector Management Assistance Program, Oct 2000).

The DSM project included many advanced programs, including market transformation of domestic manufacturers and pilot projects with Energy Service Company (ESCO). The fluorescent lights program in Thailand was the primary reason for the manufacturers to shift production. (Similar was the case in the "Golden Carrot" refrigerator program in the USA; which achieved similar market transformation.)

Thailand probably has the most extensive experience in program evaluation, having completed a detailed evaluation costing about US $4 million and engaging multiple consultants to assist in the DSM effort. Thailand's experience has underlined the importance of a concurrent evaluation process being an integral part of DSM.

Canada

The province of Quebec in Canada has provided significant emphasis on energy efficiency and DSM since 1970s. There have been 25 energy efficiency / DSM programs covering the residential, industrial and commercial sectors. Government as well as utilities undertook these multi-year programs. Initial programs for residential sector focused on heating systems and range from simple information and awareness programs to mandatory standards and regulations to providing technical and financial assistance.

Programs for industrial sector focused on providing support for energy audit and efficiency improvement studies as well as investment support. Many programs led to significant benefits. For example, a street-light efficiency program conducted during 1992 to 1995, which replaced mercury lamps with more efficient sodium lamps converting almost 250,000 luminaries, resulted in energy saving of 152 GWh.

Brazil

Recent legislation in Brazil mandates utilities to invest one percent of their revenue in energy efficiency projects (demand side and supply side). This is a large sum of money and a major commitment to efficiency improvement. Utilities are required to develop and implement DSM programs – but issues relating to finding the most efficient manner of using money would arise and would need to be sorted out. Training of staff, assembling a specialized workforce to implement DSM, project assessment capability and expertise in measurement and verification of savings are being seen as constraints. Report by Prayas Pune (Energy group) for WWF India 16

Sri Lanka

Sri Lanka had achieved a saving of 98 GWH during 1999 through DSM programs. This included information dissemination, energy audits, efficiency lighting, PF correction, appliance labelling, "best practices" group in the industry and building codes. Government funds to support these initiatives and a DSM group have been working for some time. In fact, the compact fluorescent lamp (CFL) program implemented in Sri Lanka is extremely successful.

Uruguay

A noteworthy part of DSM in Uruguay is the leasing program. UTE – a utility in Uruguay implemented a DSM scheme – whereby it tied up with a financing agency for an appliance-leasing program. UTE offered to recover the money from consumer bills. If the consumers did not pay the bill, then it had the authority to disconnect supply. The interest rates which the utility could get for the loans were half the rates commercially available to consumers. This reduced the lease payments of consumers and the utility could promote selected high efficiency appliances through 400 enlisted retailers. This approach is innovative on the backdrop of legal limitations on the utility, that it could not directly sell or lease the appliances.

China

China has also implemented a couple of large DSM programs with the help of GEF funds. In 2001, it commenced a project for removing barriers to efficient lighting products; objectives include energy saving, improving technology. China aims at reducing lighting energy use by 10% relative to a constant efficiency scenario for 2010.

In 1999, China also started a project to remove barriers to commercialisation of efficient CFC-free refrigerators. It targeted a market transformation through technical assistance and training for manufacturers, incentives for efficient product design, conversion of factory production lines, national efficiency standards, labelling program, consumer education, dealer incentive programs, and a consumer buyback/ recycling program.

Costa Rica

CNFL (The National Company for Power and Light, Costa Rica) started with energy efficiency programmes in 1992 to address the peak load problem. The major contributor to peak load was due to electric cooking and lighting. The utility's morning peak contribution from cooking was 308 W/consumer. CNFL promoted mass replacement of bulbs by CFLs and replacement of electric by LPG stoves. The Federal Government granted tax exemption to CFLs in all its marketing stages. Report by Prayas Pune (Energy group) for WWF India 17

Mexico

In 1995, Mexico started its first ever DSM project called "ILUMEX". Funds of about US $ 23 million were raised with The World Bank and GEF as major contributors. In this program, CFLs were purchased in bulk and distributed to the consumers by the utility. It was a grand success. About 2.4 Million CFLs were distributed against the target of 1.75 Million despite a severe recession in the country and peso devaluation.

Subsequent to successful completion of ILUMEX, another program called FILUMEX was promoted in 1998. It did not offer any direct subsidies to end-consumers. CFE (Commission Federal de Electricidad - Mexican utility) held a campaign to promote use of CFLs. Rest all was handled by the CFL manufacturers. This program also was a great success selling nearly 8.6 Million CFLs by 2004.

Poland

The DSM program in Poland, called PELP (Poland Efficient Lighting Project),
started in 1996. This provided subsidies directly to CFL manufacturers via a competitive bidding process. Successful bidders had to agree to pass on at least the full value of the subsidies to the product distribution chain in the form of lower wholesale prices. This approach required only a few transactions, those too at the manufacturer level. So the administrative expenses were substantially below other DSM programs that deliver subsidy directly to consumers via rebate coupons or other methods. It aimed at implementing about 1.2 Mn CFLs in 18 months.

Others

Several countries have also implemented large-scale DSM programs (especially DSM of lighting but insufficient information is available. The programs funded by the multilateral agencies like the World Bank, GEF and bilateral agencies are the ones about which sizable information is available. There are many impressive schemes that strictly do not fall under the ambit of DSM, but in the end affect the transformation of markets and have the same net effect as DSM – i.e. impact on reduction / change in consumption pattern of consumers. http://bridge.berkeley.edu/pdfs/biogasse_India_report.pdf)

2.8 CONCLUSION

This literature review shows energy systems engineering is an established scientific discipline. Energy systems engineering methodologies are based on methods and concepts developed in other disciplines, e.g. mathematics, economics, engineering, and systems engineering. Recommendations based on energy systems engineering methodologies have had a great influence on the public debate. However, the review also shows that these recommendations are already controversial and that the discipline is criticised from the viewpoint of economic theories.

Ever since the declaration of a restructured U.S. power market, there has been an identity crisis of in demand-side management. It is questioned whether demand-side management functions on a competitive electricity market. Does the approach rely on public regulations or can it be justified on a competitive market? Both opinions can be found in the literature but there is a consensual view that demand-side energy efficiency can be a strategy for gaining competitive edge, and that this strategy is more promising than competing on the basis of energy prices solely; it is a marketing tool to be used parallel to the traditional ones. Energy efficiency is suggested to be an activity for supporting energy sales.

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CHAPTER 3

THE ENERGY PRICING STRUCTURES

3.1 INTRODUCTION

The pricing structures of energy sources available to the industrial sector, namely coal, diesel, illuminating paraffin (IP), heavy fuel oil (HFO), liquefied petroleum gas (LPG) and electricity are analysed in this chapter. Where possible, price flexibility or negotiability is also included.

The mechanisms on which the different energy's prices are based vary considerably. Prices of some fuels are regulated by government and others not, some fuel prices are based on a zone pricing structure, some have a "base" wholesale price and delivery costs account for area price difference, and other fuel's prices are very much at the discretion of the supplier. Some energy also has a complicated pricing mechanism influenced by a number of factors. The degree of price negotiability of the various fuels differs and is also very supplier and customer specific (Stigler 1971). The main price variation in energy costs in South Africa is between coastal and inland prices, primarily due to transportation or delivery costs.

3.2 METHODOLOGY

To provide pricing structures and/or mechanisms of energy sources available to the industrial sector. Additionally, where possible to include price flexibility and negotiability. In order to obtain and verify prices of the various energy sources, unstructured telephonic discussions were conducted with:

- Colliery
- Afrox
- Engen
- Easigas (Shell)
- Total SA
- Sasol Gas
- Mossgas
- Spoornet

- Sapref
- Natref
- Enref
- Eskom Pricing Manager (Polokwane)
- Johannesburg Metro City Treasurer's Office
- Durban Metro City treasurer and Electrical City Engineer
- Port Elisabeth Electrical City Engineer
- Bloemfontein (Botshabelo) Electrical City Engineer
- Nelspruit (Mbombela) City Treasurer
- Polokwane City Treasurer
- Richard Bay (uMhlathuze) Electrical City Engineer

3.3 COAL

Many grades of coal having differing combustion and other characteristics are available on the South African market. Prices, which are unregulated, are generally determined by the economics of supply and demand (Risling & Steen 1993). Coal prices mainly depend on coal quality and transport or delivery costs. There is a comparatively large regional price variation due to the cost of transport from colliery to consumer. Coal quality or grade includes various characteristics such as chemical composition, size, calorific value and ash content. Higher-priced grades generally have a higher calorific value and lower ash content.

3.3.1 Comparative Prices (excluding transport charges)

The price per ton of coal varies considerably. The various sectors require coal types with unique characteristics such as ash, moisture, volatile matter, fixed carbon and sulphur content. Prices vary considerably with quality as well as size (cobbles, nuts, peas, duff, etc). Coal used in industrial applications is usually A- or B-grade bituminous coal with an average calorific value (c.v.) of about 28MJ/kg. The average collieries price of bituminous coal – industries sector is R175.26/ton pertaining to March 2005.

3.3.2 Transport Charges and Prices of Delivered Coal

Transport costs significantly increase coal prices in areas remote from the coalfields. Approximate transport charges for delivered coal are 17 - 24 c/ton.km for rail and 44 - 60 c/ton.km for road. Charges per km decrease with increasing distance. Transportation costs are very significant – more so for coal than for any other energy source. If rail transportation is used, customers are required to have a side railing; an offloading facility and the ability to receive at least 10 loads @ 350 tons at a time.

3.3.3 Coal Price

Coal transportation costs impact heavily on delivered prices of coal. The cost of delivered coal can be twice to three times the actual colliery price depending on the distance from the colliery. For long distance deliveries such as Witbank – Cape Town, transportation costs account for more than half of the final price. The average delivered price of bituminous A-grade coal is R241 to R300 per ton delivered inland and R288 to R 448 per ton delivered coastal as per June 2005.

3.4 DIESEL

The diesel price in South Africa is directly linked to the international price of diesel, which in turn depends on the crude oil price (Kaufman 1994). The ex-refinery price of diesel is deemed to be the same as the in-bond landed cost (IBLC), which is based on a basket of term and spot prices (80:20 ratio) at three refineries in Singapore and one in Bahrain, to which ocean freight, insurance and leakage costs are added. Costs are converted from US $ to SA Rand. This price allows for the cost of crude oil, refinery operational costs and profit. To this is added a wholesale margin (based on an assessment of Oil Industry assets), fuel tax, customs and excise, road accident fund levy, an IP-marker levy and transport and delivery costs.

3.4.1 Price Basis

The retail diesel price is unregulated. The government calculates and publishes a recommended wholesale list price for diesel (together with the regulated pump price of petrol). These calculations are done by the Central Energy Fund (Pty) Ltd on behalf of the Department of Minerals and Energy, and prices are adjusted on the first Wednesday of each month.

The wholesale price build-up for June 2005 is given in Table 3.1 for the coast (zone 1A) and PWV (zone 9C).

TABLE 3.1: Wholesale Price build-up for Diesel as per June 2005

Price element	**Coast (c/l)**	**PWV (c/l)**
Basic price	268.96	218.96
Unit over/ (under) recovery	3.91	3.91
Slate levy	9.00	9.00
Fuel tax	90.96	90.96
Customs & Excise	4.60	4.60
Road Accident Fund	11.85	11.85
IP Tracer levy	0.18	0.18
Zone differential	0.12	12.99
Wholesale margin	21.60	21.60
Service differential	5.87	5.87
Recommended wholesale price	367.05	379.92

Source: Energy Branch, Dept. Minerals & Energy.
pertaining to 15 June 2005.

3.4.2 Zone Price Structure

The diesel price, similar to the petrol price, is lowest at the coastal ports (zone 01) and increases with increasing distance to inland regions. The zone price structure is an extension of the IBLC principle of linking local prices to international prices and incorporates the cost of transporting fuels from the coastal oil refineries. For ease of regulation and administration of prices, the price zones are based on the magisterial districts of South Africa. There are 32 zones. Northern Namaqualand (zone 32) is farthest from the coast and therefore is the region with the highest fuel prices. It should be noted that although Sasol produces diesel inland at Sasolburg and Secunda, these refineries are deemed coastal refineries for pricing purposes. Sasol thus enjoys a geographic price advantage. For this reason, Sasol tends to market product in an optimised distribution area, which extends more inland than towards the coast.

3.4.3 Diesel Price

Retail diesel price (also known as pump price) includes a recommended additional retail margin of 13.7 c/l. Unlike the petrol price, which is strictly regulated and therefore the same throughout a given price zone, diesel prices may vary as a result of different marketing strategies employed by the oil companies and/or service station industry.

The recommended wholesale price as per June 2005 for diesel is on average 368 cents/litre (c/l) at the coast (e.g. zone 1A = 367.22 c/l) and on average 382 c/l inland (e.g. zone 10C = 348.23 c/l).

3.4.4 Price Negotiability

As the recommended wholesale and retail selling prices of diesel are unregulated (apart from the fixed government levies and taxes that form part of the selling price), high-volume customers usually negotiate price rebates with the oil companies. Exact details are customer-specific and confidential, but rebates are usually less than 12 cents/litre or about 3%.

3.5 ILLUMINATING PARAFFIN

Illuminating paraffin (IP) has no fuel tax levied on it. As From 3 April 2005, the government decided to zero-rate VAT on this fuel because of its important role as a domestic fuel for impoverished communities. The impact of eliminating tax on IP is expected to be minimal in the case of industrial and commercial use, since IP is input cost and the VAT is therefore recoverable.

3.5.1 Price Basis

The price of IP is unregulated although the Department of Minerals and Energy publishes a recommended wholesale price or reference price on a monthly basis. Retailers often add a substantial margin to the wholesale price in the case of small volume customers. The zone pricing structure is used to determine recommended wholesale prices in different regions.

3.5.2 IP Price

The recommended wholesale price as per June 2005 for IP is on average 271 cents/litre at the coast (e.g. zone 1A = 268.99 c/l) and on average 293 c/l inland (e.g. zone 10C = 291.51 c/l).

3.6 HEAVY FUEL OIL

HFO prices are not regulated and there is no common list of prices for different regions (zone pricing). Consequently, the individual oil companies may have different prices at different times. About 67% of the total HFO demand of about 500 Ml/yr. is in coastal areas and the remainder are inland (Risling & Steen 1993). The highest inland demand is in Gauteng (approx. 120 Ml/yr), followed by Mpumalanga (approx. 60 Ml/yr).

Although most oil companies with coastal refineries can supply to inland customers, the major supplier in these areas is Sasol, from the Natref oil refinery at Sasolburg and the oil-from-coal plants at Secunda. Otherwise, the product is railed from the Durban refineries (Sapref and Enref).

3.6.1 HFO Price

The price of HFO as per June 2005 for bulk deliveries is on average 175 c/l at the coast and 202 - 213 c/l inland. Actual prices are volume dependent and may be above or below the given price. Also, the capital cost of the tank storage facilities and associated equipment installed by the oil company at the customer's premises may sometimes be recovered by way of a higher fuel price.

3.6.2 Price Negotiability

Due to HFO being mostly sold in large volumes as boiler or furnace fuel directly to customers by the oil companies, 'wholesale' and 'retail' prices are not relevant. Discounts are usually given to large-volume customers (>50 000 litres/month). Volumes of 10 000 to 20 000 litres/month would not normally attract large discounts.

3.7 LIQUEFIED PETROLEUM GAS (LPG)

LPG prices are unregulated and usually quoted per kg rather than per litre because of density variations. Prices are not regulated but the LPG industry publishes list prices for the various geographic areas of South Africa as a guideline to resellers. No fuel tax or levies are imposed on LPG but the product is subject to VAT.

The leading distributor of LPG is Afrox, with approximately 44% market share, followed by BP, Easigas (Shell), Total SA, Elf and Engen (bulk only). LPG is distributed in cylinders (9, 19, and 48 kg) and in bulk (to customers with storage tanks). The product is distributed countrywide by rail and/or road tankers to branches and customers. Smaller distributors (also called resellers) purchase LPG from the major distributors in cylinders or in bulk and fill cylinders on site for customers. Large customers requiring bulk storage facilities usually purchase LPG directly from the major distributors by way of 3-5 year supply agreements that often include a rental agreement for the bulk tank installation.

The total LPG sales volume in South Africa is currently about 315 000 tons/yr. of which 60 000 tons/yr. is sold in cylinders of various sizes. The number of cylinders in circulation is estimated at 3.73 million, representing a significant investment by the LPG industry.

3.7.1 Price Basis

LPG is supplied by the refineries to the major distributors at a so-called LPG Producer Price, which is set by the oil industry and adjusted from time-to-time. The coastal oil refineries, Sasol and Mossgas supply LPG to the major distributors at a base price called the Producer Price, which is equal to the in-bond landed cost of Mogas 93 (petrol) less 1.15c/kg. Refinery terminal and gate fees, safety levy (to fund the LP Gas Association) and rail or road transportation costs are added to the base price. The distribution of LPG to virtually all the populated areas of South Africa is a highly capital-intensive industry. Costs that are generally incurred and which need to be recovered in the selling price of LPG are the following:

- Cylinder and plant investment
- Bulk and cylinder filling operations
- Plant and cylinder maintenance and repair
- Marketing, office and management overheads
- Skilled training requirements
- Distribution of product by rail and/or road.

Since the cost of distribution is a major component of the final cost, LPG prices increase significantly in elation to the distance between the refineries and the customer. The various price components vary between the major distributors and are company confidential.

3.7.2 LPG Price

The recommended list price excluding VAT pertaining to June 2005 for direct bulk supplies of LPG to end-users is on average R6.33 /kg at the coast (e.g. zone 07L = R6.67 /kg) and on average R6.67 /kg inland (e.g. zone 08L = R6.77 /kg).

Recommended list prices for smaller volumes in various cylinder sizes (9 to 48 kg) are between 1 and 3% higher than bulk prices. LPG unit prices are highest when supplied in small cylinders. As retail prices are not regulated, some resellers add a higher margin than recommended by the major distributors.

3.7.3 Price Negotiability

With several LPG distributors in the South African market, competition is strong and customers are in a position to benefit from the non-monopolistic market. The LPG industry uses a zone-pricing structure for price guidelines, although competing distributors will often give rebates to large customers. Small customers are sometimes charged more than the recommended price. As a general rule the major distributors are unlikely to give rebates higher than 15-20% to high-volume bulk customers (end-users and resellers) due to distributor margin limitations as a result of a variety of costs incurred in the distribution chain.

3.8 ELECTRICITY

Prices are based on tariffs and charges determined by Eskom or the local authorities in the various metropolitan areas, as approved by the National Electricity Regulator. VAT is excluded in all cases. This report discusses electricity tariffs for the following municipal areas: Johannesburg, Durban, Port Elizabeth, Cape Town, Bloemfontein, Nelspruit and Pietersburg.

3.9 ESKOM TARIFFS

Tariffs for industrial users of electricity are Nightsave, Megaflex and Miniflex. The latest tariff structures and costs can be obtained from the Eskom Tariff Book.

3.9.1 Johannesburg: Industrial Tariffs

The Greater Johannesburg Metropolitan Council tariffs given below are effective to 30 June 2005 and tariff increases effective 1 July 2005 average 6.3%. Two tariffs are applicable for industrial applications, namely the Demand tariff and the Off-peak tariff.

- Demand tariff for non-domestic consumers (minimum 100kVA). Service charge: R142.00/month. Active energy charge: 11.58 c/kWh. Maximum demand charge: R63.10/kVA.month. Reactive energy charge: 2.49c/kvarh in excess of 30% (0.96 power factor) of recorded kWh. Minimum demand charge: 80% of average of 3 highest readings recorded during preceding May – August period, applicable for each monthly account until new average is calculated. The maximum average energy charge is 75.75c/kWh.
- Off-peak tariff. Service charge: R283.00/month. Energy charge: 11.58 c/kWh. Maximum demand charge: R61.10/kVA.month, peak periods only. A discount of

1% for supply voltages >1000V and a transformer rebate of 36.35c/kVA where no Council transformers are installed, are applicable.

3.9.2 Durban: Industrial Tariffs

Durban Metro Electricity is in the process of rationalising tariff structures to simplify and reduce the number of available tariffs. Consequently, several tariff structures that apply to existing users are no longer available to new customers. Tariffs effective to 31 December 2005 for industrial use are given below. They are divided into two categories, namely Business, two scales and Bulk Supply Agreement Tariffs 3-part and time-of-use.

Business tariffs for industrial customers for 230V, 400V, 6.6kV and 11kV supplies are as follows:

- Scale 1 (Business & General). Service charge: R53.11/month. Energy charge: 37.22 c/kWh with 2% rebate for voltages exceeding 1000V.
- Scale 2 (Two-rate). Service charge: R51.91/month. Energy charge: 13.98 c/kWh plus 32.78 c/kWh for energy used between 07h00 and 19h00, Monday to Friday, with a 2% rebate for voltages exceeding 1000V.

Bulk Supply Agreement Tariffs are generally for 230V, 400V, 6.6kV, 11kV, 33kV and 132kV supplies are as follows:

- LV 3-part. This tariff applies to a 400V supply to customers who are able to restrict their electricity consumption during the late afternoon. Charges are as follows: Service charge: R263.07/month. Energy charge: 11.88 c/kWh. Maximum demand charge: R99.44/kVA.month. A restricted demand discount of R12.34/kVA is applied to the difference between the notified maximum demand (NMD) and the actual maximum demand. The bulk supply agreement is for a minimum period of 12 months and the minimum charge is for 70% of the NMD or 100kVA, whichever is the greater. A 1-% general discount is applied for a notified minimum demand of 2000kVA.

- Time-Of-Use. Designed for customers with bulk supply requirements in excess of 1MVA per month. Half-hourly maximum demand is measured during peak and standard hours and is charged at R15.27/kVA.month during high-demand months of June, July and August and R13.76/kVA.month during the other months. The active energy charges for high-demand months during peak, standard and off-peak hours are 37.90, 15.84 and 9.09 c/kWh respectively, and for low-demand months these charges are 25.38, 14.26 and 8.68 c/kWh respectively. In addition, an overall maximum demand charge of R21.33/kVA is applicable. A sliding scale discount of 1% to 32.5% is given for a notified minimum overall demand from 1MVA to 100MVA, and a discount on all charges of between 4.0% and 8.67% applies for voltages over 400 volts (6.6kV to 275kV).

3.9.3 Port Elizabeth: Industrial Tariffs

The tariffs given below are effective to 30 June 2005. Tariff increases as from 1 July 2005. Three tariffs, namely Medium Business (400V 3-phase, maximum 800kVA), Large Business (6.6kV and above) and Alternative Peak/Off-Peak Demand tariffs are available for industry.

- The Medium Business tariff has 3 options which apply for urban areas:
  - Single Rate. Basic charge: R30.31/month. Energy charge: 35.734 c/kWh. No maximum demand charge.
  - Multi-Rate. Basic charge: R138.95/month. Energy charge: 44.285 c/kWh (peak), 14.314 c/kWh (off-peak). No maximum demand charge. Peak periods are weekdays 7am - 8pm (excluding public holidays). Off-peak are at all other times.
  - Metered Demand Rate. No basic charge per month. Energy charge: 18.671 c/kWh. Maximum demand charge: R33.74/kVA.month. Minimum monthly demand charge based on 70kVA.

- The Large Business tariff has 2 options:
  - Metered Demand Large Business. Energy charge: 17.490 c/kWh. Maximum demand charge: 30.85/kVA.month. Minimum monthly demand charge based on 70kVA. Voltages over 66kV are subject to a discount of 1%.
  - Time-of-Use (TOU) tariff. Available as an option to consumers with maximum demand over 1MVA. Peak, standard and off-peak hours are applicable. Maximum demand charge (not measured during off-peak) for winter (April – September): R22.77/kVA.month, and for summer (October – March): R20.53/kVA.month. Energy charges for peak, standard and off-peak hours for winter: 37.353, 20.911 and 12.448 c/kWh, and in summer: 33.582, 18.199 and 10.994 c/kWh, respectively.

- The Alternative Peak/Off-Peak Demand tariff is an option whereby consumers on a Metered Demand tariff can chose to have their demand metered separately for peak and off-peak hours, with the kVA charge during off-peak periods charged at 50% of the peak demand charge. The minimum demand charge is calculated at the peak rate.

3.9.4 Cape Town: Industrial Tariffs

Tariffs are effective to 30 June 2005. Three rates are available, as follows:

- Rate 4 (Large user). Low-voltage rate for large users (max. 1MVA). Energy charge: 15.53 c/kWh. Maximum demand charge: R43.66/kVA.month (integration period: 30 minutes) subject to a minimum monthly payment of R4255.
- Rate 5A (MV Large user). Priced as for Rate 4 less 7% on energy and maximum demand charge, except that the maximum demand charge is only incurred from 6am to 11pm on weekdays excluding public holidays.
- Rate 5B. Interruptible supply for steam generation. Available at a special Eskom tariff subject to a voltage discount, transmission surcharge and municipality surcharge to cover the cost of using the Cape Town MV transmission system.

Tariff changes and increases for industry, effective 1 July 2005 are as follows:

- Rate 4 (Large user). Demand charge: R47.84/kVA.month. Energy charge: 16.33 c/kWh.
- Rate 5A (MV Large user). As for Rate 4 less 7% on energy and maximum demand charge, as before.
- Rate 5B. Interruptible supply for steam generation. Available at a special Eskom tariff subject to a voltage discount, transmission surcharge and municipality surcharge, as before.

3.9.5 Bloemfontein (& Botshabelo): Industrial Tariffs

Tariffs are effective to 28 February 2005. The tariff group most suitable for industrial use is Urban Tariff III (Bulk). This is a maximum demand tariff for the supply of electricity at low voltage (LV) or high voltage (HV) at 11kV or 33kV. Monthly service charge: R219.00. Standard maximum demand charge: LV - 7.00/kVA.month, HV – R50.55/kVA.month. Off-peak maximum demand charge: LV – R46.26/kVA, HV – R43.09/kVA. Energy charge: 14.30 c/kWh.

3.9.6 Nelspruit (Mbombela): Industrial Tariffs

The electricity tariffs given below were effective to 30 June 2005. Two tariffs apply for industrial usage:

- Elephant. For industrial or factory undertakings. Tariff is for 400V or 230V supply up to 80 amperes. Fixed charge: R118.77/month. Energy charge: 38.58 c/kWh
- Lion. For bulk consumers in excess of 80 amperes, 3-phase (55kVA). The following charges apply: Maximum demand charge: R44.89/kVA.month measured over 30-minute integration periods or R12.55/ampere.month measured by 3 ampere meters per consumer. Energy charge: 21.99 c/kWh. All connection costs greater than 80-amp current limited single-phase to be paid by the applicant.

Tariff changes and increases from 1 July 2005 are as follows:

- Elephant. Fixed charge: R138.00/month. Energy charge: 39.67 c/kWh.
- Lion. For bulk consumers requiring low voltage (380/220V). Fixed charge: R138/month. Maximum demand charge: R59.00/kVA.month or R15.87/ampere.month measured by 3-ampere meters per consumer. Energy charge: 19.40 c/kWh.
- Cheetah. For bulk consumers requiring high voltage (6.6kV and 11kV). Fixed charge: R138/month. Maximum demand charge: 56.36/kVA.month or R15.88/ampere.month measured by 3-ampere meters per consumer. Energy charge: 18.54 c/kWh. Discount: Up to 4%.

3.9.7 Pietersburg (Polokwane): Industrial Tariffs

The tariffs given below are effective to 31 July 2005. Two tariffs apply one for smaller industries and one for a bulk supply.

- Industries. Maximum demand restricted to 100 amperes per phase on a 3-phase supply. Basic monthly charge: R15.25 for the first 2000 m^2 of erf size plus R2.99 per 1000 m^2 thereafter, with a maximum of R3180.25. Energy charge: 43.34 c/kWh. An alternative tariff is available which has a lower energy charge of 38.87 c/kWh plus a monthly demand levy of R265.93 for a 3-phase supply (100 amp/phase).
- Bulk supply. For demand in excess of 100 amperes per phase on a 3-phase supply. Service charge: R96.77 per month. Demand charge: R55.09/kVA.month. Energy charge: 19.172 c/kWh for initial 100 000 kWh, thereafter 18.40 c/kWh. Minimum monthly charge: R2493.82.

3.10 CONCLUSION

The mechanisms on which the different energy's prices are based vary considerably. Prices of some fuels are regulated by government and others not, some fuel prices are based on a zone pricing structure, some have a "base" wholesale price and delivery costs account for area price difference, and other fuel's prices are very much at the discretion of the supplier. Some energies also have a complicated pricing mechanism influenced by a number of external factors. The degree of price negotiability of the various fuels differs and is very supplier and customer specific (Peltzman 1976).

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CHAPTER 4

INTERPRETATION OF PRICICNG STRUCTURE

4.1 INTRODUCTION

This study was undertaken to compare the latest available energy prices in South Africa and to determine energy costs related to using various energy sources. Energy sources available to the Industries sector, namely coal, coal gas, diesel, illuminating paraffin, heavy fuel oil, liquefied petroleum gas and electricity, were compared in eight geographic areas. These are the inland areas PWV, Bloemfontein, Pietersburg and Nelspruit, and the coastal areas Cape Town, Durban, Port Elizabeth and Richards Bay. The energy prices for June 2005 were calculated on an energy equitable basis by converting to comparative prices expressed in c/MJ. For electricity where several tariffs are available, the most suitable tariff for general industrial use was selected. A summary of the results for the various areas, expressed in relative terms where Eskom electricity in the PWV is equal to 100 price units per MJ is given below (Cleveland et al. 1984).

4.2 METHODOLOGY

Information of various boiler specifications, types and designs for steam production, used in the industrial sector was gathered through e-mails, telephone deliberations, faxed data and consultations with:

- **John Thompson, Johannesburg**
- **Marshall Fowler, Johannesburg**
- **Steamers, Durban**
- **E B Steam, Cape Towm**
- **Spirax Sarco**
- **Lodine Redelinghuys, Industrelek, Specialist, Distribution, Eskom**
- **Ash Resources (Pty) Ltd**
- **Sham Singh, Environmental Practitioner, Generation, Eskom**
- **Clive Nicosia, Industrelek Specialist, Distribution, Eskom**

TABLE: 4.1 Summary of Relative Energy Prices for various Areas

Relative energy prices (Eskom electricity = 100 in PWV)

Energy source	**PWV**	**Durban**	**Port Elizabeth**	**Cape Town**
Coal	16	24	34	34
Eskom electricity	**100**	**101**	**102**	**103**
HFO	**102**	**89**	**89**	**89**
Coal gas	134	134	N/A.	N/A.
Metro electricity	149	138	147	141
IP	167	155	155	155
Diesel	213	205	205	205
LPG (bulk)	286	258	300	259
(Continued)	**Bloemfontein**	**Nelspruit**	**Pietersburg**	**Richards Bay**
Coal	22	20	20	20
Eskom electricity	**101**	**101**	**101**	**101**
HFO	**105**	**105**	**108**	**89**
Coal gas	N/A.	N/A.	N/A.	134
Metro electricity	149	191	187	126
IP	168	168	171	159
Diesel	214	214	217	210
LPG (bulk)	286	291	291	282

Source: National ElectricityRegulator and dept of Mineral & Energy

It was realised that energy sources should be evaluated on an effective-cost basis, taking account of energy price as well as indirect costs and utilisation efficiencies. This study is an analysis of fixed and variable costs associated with using various energy sources and associated equipment for steam production in order to gain a better understanding of the total cost of using these energy sources as opposed to comparing costs on a simple energy equitable basis (Slesser 1976).

The study includes, where possible, costs of transport or delivery, storage, materials handling, labour, capital and prevention of environmental pollution. The results are calculated in terms of cost per unit of steam produced. The issue of energy utilisation efficiency and the idea of determining energy costs per unit of production as the most equitable basis for comparing energy sources are examined.

4.3 ENERGY COST ANALYSIS FOR STEAM GENERATION

For a true comparison of the total costs of different energy sources, not only the direct energy cost (in energy equivalent terms) but also the additional or indirect costs, often associated with the use of non-electrical energy especially in the case of coal, as well as the utilisation efficiency needs to be taken into account. For example, coal use requires additional labour, materials-handling equipment, plant maintenance, ash disposal and environmental anti-pollution measures. Effective energy costs are likely to be dependent on the type of equipment and process, possibilities for electrical load shifting and various other considerations.

An evaluation of several of the more significant additional cost-factors is done below for a typical industrial energy use, namely steam production. It should be noted that it is not possible to accurately determine all of the energy-related costs without being user-specific in terms of the actual energy application (Hall et al. 1986)

4.4 INDUSTRIAL BOILERS

Many different types and designs of boilers for steam production are used in the industrial sector and it would be an onerous task to detail each one. However, it was considered prudent to evaluate the operation of a limited range of boilers produced and marketed in South Africa by one of the largest boiler manufacturers, namely John Thompson Africa. Such an evaluation is considered to be representative of general boiler performance (Tissot 1979).

4.4.1 Coal-Fired Boilers

Coal-fired boilers are the most common types and are used for a variety of industrial applications where steam or hot water is required from 1000kg/hr to over 100000kg/hr. Various designs are available, e.g. vertical or horizontal, 2- or 3-pass with conventional wetback (water-cooled outer shell), firetube (for general industrial use) or watertube (for larger plant), fixed grate or single/twin chaingrate stokers, etc). The following are examples of typical steam boiler characteristics for general industrial use:

Rating: 750kW – 13000kW

Size: 9m x 4m x 5m high (mid-range)
Capacity: 1200kg/hr – 21000kg/hr of steam
Pressure: 9.6 bar (up to 20 bar available)
Efficiency: 80% - 82% (gross)

Advantages:

- Long life due to robust design and construction
- Cost of steam is lower than for other boilers/fuels

Disadvantages:

- Capital cost is higher than for other boilers
- Coal storage bunker required
- Auxiliary equipment required (coal feed systems, pollution control, etc)
- Stringent maintenance and labour requirements
- Dust and grit is accumulated
- Low turn-down ratio (limits fuel saving)

4.4.2 Gas and liquid Fuel-Fired Boilers

Packaged boilers that use gas (Sasol gas or LPG) or liquid fuel (HFO, diesel or paraffin) mostly have the same design concept except for the burner, which is specifically tailored for the particular fuel type. General characteristics of these boilers are as follows:

Rating: 630kW – 20000kW
Size: 8m x 4m x 5m high (mid-range)
Capacity: 840kg/hr – 13400kg/hr of steam
Pressure: 10 - 11 bar (up to 25 bar available)
Efficiencies: HFO: 82.5% - 85% (gross)
Gas: 78.5% - 82% (gross)

Advantages:

- Lower capital cost compared to coal-fired boilers
- Less auxiliary equipment required

- Clean operating environment
- Higher turn-down ratio, resulting in less fuel wastage (especially in the case of gas-fired boilers)

Disadvantages:

- Relatively high and unpredictable fuel price
- Cost of liquid fuel storage facility
- High cost of steam

4.4.3 Electrode Boilers

These boilers are used to produce steam and hot water from 30kg/hr to 6400kg/hr or more at pressures up to 10 bar. Low- and high-pressure steam versions are available – similar types are produced by other manufacturers such as Steamers (Durban) and EB Steam (HV Boilers), the latter being high voltage, high steam capacity electrode boilers (over 10000kg/hr).

Typical characteristics are as follows:

Low pressure
Rating: 20kW – 600kW
Size: 0.25m^2 x 2m high (mid-range)
Capacity: 32kg/hr – 960kg/hr of steam
Pressure: 0.4 bar
Efficiency: 98%

High pressure
Rating: 20kW – 4000kW
Size: 1m x 2m x 2.5m high (mid-range)
Capacity: 30kg/hr – 6400kg/hr of steam
Pressure: 10.3 bar
Efficiency: 98%

Advantages

- Less capital cost than other boiler types
- Very high heat transfer efficiency
- Short start-up period
- Fully automatic
- Compact size
- No fire risk
- No pollution
- No boiler-house
- No fuel storage

Disadvantages:

- Electrical energy more expensive than coal
- Periodic electrode maintenance

4.5 ENERGY REQUIREMENTS FOR STEAM GENERATION

Steam has an enthalpy (heat content) of 2.78MJ/kg at a gauge pressure of 10 bar. The enthalpy is only marginally dependent on pressure as shown in Table 4.2 (See Appendix A).

TABLE 4.2 STEAM SPECIFICATIONS

Pressure (bar)	Temp. (^{O}C)	Vol. (m^3/kg)	Enthalpy (MJ/kg)
0	100	1.67	2.68
0.5	112	1.15	2.69
1	120	0.88	2.71
5	159	0.32	2.76
10	184	0.18	2.78
20	215	0.09	2.80

Source: Spirax Sarco Ltd - Steam tables.

The quantity of steam generated by 1kg of fuel using a boiler with efficiency η_e is found by multiplying the gross calorific value of the fuel by η_e and dividing this by the enthalpy of the steam at the given pressure. (See Appendix A)

Examples:

(1) A coal-fired boiler, rated at 82% efficiency, produces steam at a pressure of 10 bar and operates using coal with gross calorific value 28MJ/kg. The quantity of steam generated per kg of coal is:

28 x 80% / 2.78 = 8.0kg/hr.

(2) An electrode boiler, rated at 98% efficiency, produces steam at a pressure of 0.5 bar. The quantity of steam generated per unit of electricity is:

3.6 x 98% / 2.69 = 1.3kg/hr

Note: The "calorific value" of electricity is 3.6MJ/kWh.

4.6 COMPARISON OF STEAM COSTS FOR DIFFERENT BOILERS

Assume an industrial undertaking in the PWV area (Johannesburg Metro) has an existing electricity demand of 1000kVA and uses 300000kWh/month for rotating machinery, lighting and various other purposes (42% load factor).

Existing electricity cost (non-steam applications):

Johannesburg Metro electricity account for June 2005:

Service charge	R 141
Max. demand (1000kVA @ R53.10/kVA)	R61065
Energy charge (30000kWh @ 9.58c/kWh)	R33051
Total	R94257

The effective cost of the existing electricity supply is the total cost divided by the kWh's =31.4c/kWh. Assuming that steam is required at a continuous rate of 1000kg/hr, it can be shown that using an electrode boiler will reduce the effective cost of the existing electricity supply as a result of the increase in the load factor. – see par. 4.6.3(4)

4.6.1 Coal-Fired Boiler

Fuel cost:

The efficiency of a coal-fired boiler operating at 10 bar is about 80% (gross) when new or very well-maintained, and provided that good quality coal with calorific value of 26 – 28MJ/kg) is used. In this case about 8kg of steam is produced per kg of coal - see par. 4.5(1). Steam production can decrease to 7kg or less, per kg of coal as the boiler ages due to poor heat transfer resulting from dirt, scaling, etc. Preventative maintenance of boilers, including water treatment to limit scaling and loss of heat transfer is therefore very important (http://www.isr.gov/coal).

In this comparative study, the rule of thumb used is:

$$\boxed{\text{1kg Coal} \equiv \text{8kg Steam}}$$

If the boiler is operated continuously, production of 1000kg/hr of steam would result in a monthly coal consumption of (1000 / 8000) x 24 x 30 = 90 tons. For a delivered price of R213/ton, the total cost would be R19147/month. The steam cost, based only on the price of coal, would be R26.59/ton.

Additional costs

Coal has a multitude of additional costs, as listed below:

- Capital investment in auxiliary equipment (bunker, bins, feed, stoker, etc)
- Transportation
- Handling
- Storage
- Ash disposal
- Equipment maintenance
- Flue-gas cleanup
- Hearth damage due to slag formation

It is not feasible to quantify all of the above costs as they are dependent on specific circumstances but on a comparative basis, the following is generally true (Bullard 1976):

- The capital investment in equipment required to store, load and transport coal from bunker to boiler, as well as that required for handling and disposing of ash and clinker material is significantly more than that required for other fuel types for similar steam capacities.
- Maintenance of boilers is necessary to ensure efficient operation, and these costs are generally about the same for all fuel types except for electrode boilers, which are generally associated with lower maintenance costs. Maintenance costs depend on many variables including the size and age of the boiler (tending to increase significantly for older boiler installations), making generalisations difficult as an example, a typical small industrial boiler plant in the Jacobs Industrial area (Durban), operating continuously, had a reported maintenance cost of R3500/month.
- Coal-fired boilers are more labour intensive. Apart from a qualified boiler-house manager or engineer/foreman, at least 4 unskilled or semi-skilled shift-workers (depending on the number and size of boilers) are needed to handle the coal-feed and boiler operations. The additional labour requirement (excluding engineer) is estimated to cost a minimum of about R20000/month, including overheads.
- Costs of ash and clinker disposal can vary considerably depending on location and availability of dumping sites. Ash in significant quantities from selected Eskom power stations is processed by a company called Ash Resources (Pty) Ltd and utilised as a cement extender in the cement industry and as filler for other types of materials such as plastics. There is not a viable market for small quantities of ash and clinker material produced by coal-fired industrial boilers at most of the industrial sites in the areas studied. If not dumped on site, transport and handling costs incurred for off-site removal of ash are likely to be in the region of R1000/month for a small to medium-sized boiler.
- Reduction of environmental pollution is another cost factor that needs to be taken into consideration in the longer term. Measures to remove sulphur and fly ash (by filters or electrostatic precipitation) from boiler flue-gas are very costly, but may be required as local authorities in South Africa enforce stricter air pollution standards. At this stage it is not possible to quantify such costs for industrial boiler applications.

In comparing coal-fired boilers to all other types, the main additional costs appear to be associated with maintenance, labour and ash disposal. Based on several case studies for 1000kg/hr-steam production these costs appear to be around R230/ton of coal consumed, or about R2127.59/month. Clearly these additional costs, per ton of coal or steam, will decrease for higher steam production rates and could be as low as R23/ton of coal for 10000kg/hr-steam production.

Estimates of the total monthly cost of operating typical industrial coal-fired boilers continuously supplying 1000kg/hr and 10000kg/hr of steam, excluding professional staff, fixed costs and various minor expenses (rounded to nearest R1000) are given in Table 4.3

TABLE 4.3: Monthly and Unit Cost of Steam Production

Costs	***Steam production rate (kg/hr)***	
	1000	***10000***
Fuel (R/month)	19550	195500
Additional (R/month)	5750	28750
Total	25300	224250
Unit cost of steam (c/kg)	6.7	3.2

Source: Max Cruz of John Thompson SA

4.6.2 Gas and liquid Fuel-Fired Boilers

Fuel cost:

A well-maintained gas boiler operates at an efficiency of about 80% compared to about 83% for a liquid fuel-fired boiler (HFO, diesel or paraffin). The amount of steam produced per gigajoule of fuel consumed, for gas and liquid fuel-fired boilers operating at a steam pressure of 10 bars, is given below:

1GJ (Sasol gas / LPG) ≡ 290kg Steam

1GJ (Diesel / HFO / IP) ≡ 300kg Steam

The following table lists the approximate steam yield for the different fuels based on the gross calorific values of these fuels.

TABLE 4.4: Boiler Steam Production for Gas & Liquid Fuels

Fuel	**Calorific value**	**Fuel quantity**	**Steam produced (kg)**
Sasol gas	18.9MJ/m^3	1 GJ	290.0
Diesel	38.1MJ/l	1 litre	11.4
IP	37.0MJ/l	1 litre	11.1
HFO	**41.6MJ/l**	**1 litre**	**12.5**
LPG	49.6MJ/kg	1 kg	14.4

Source: Bill Cochran, EB Steam, Johannesburg

If the boiler is operated continuously (24hrs/day, 30days/month) and produces steam at a rate of 1000kg/hr, the monthly consumption and cost of fuel is as given in Table 4.5 for the PWV area.

TABLE 4.5: Approximate Monthly Fuel Consumption & Fuel Costs For 1000kg/hr Steam (10 Bar) – PWV Area

Fuel type	**Consumption/month**	**Cost R/month**
Heavy Fuel Oil	**57600 litres**	**115000**
Illuminating Paraffin	64865 litres	187000
Sasol gas	2483 GJ	203000
Diesel	63158 litres	240350
Liquefied Petroleum Gas	50000 kg	328000

Source: Lodine Redelinghuys Industrelek Boiler Specialist

Note:

(1) Rounded to nearest R1000.

(2) Based on June 2005 list prices but subject to volume-based discounts.

Additional costs:

Boiler maintenance is the only significant additional cost associated with the use of Sasol gas (apart from once-off connection fees). Liquid fuels such as diesel, IP and HFO require investment in tank storage, pumps and piping, which increases the overall capital cost. Often suppliers (Oil Companies) will install this equipment for a monthly rental charge, or at no charge in the case of supply contracts of 4 to 5 years (the equipment is written off over this period).

Electrical heating equipment to improve product viscosity in the case of HFO fuels may also be required and is usually included in the storage/pump/piping supply package. LPG also requires an additional investment in pressurised tank storage and piping. This cost can either be incorporated in the price of the LPG or by payment of a monthly rental to the LPG distributor for use of the facility, which remains the property of the distributor.

The above-mentioned additional costs depend on a variety of specific circumstances and cannot be accurately quantified. However, based on a survey of a few companies with small to medium-sized boilers in the PWV and Durban areas, maintenance is usually done every 3 months and averages about R11500/yr. Boiler inspection (at somewhat higher cost) is a legal requirement but occurs at less frequent intervals.

Comparative estimates of the total monthly cost of operating some typical industrial gas or liquid petroleum fuel-fired boilers with capacities of about 1000kg/hr of steam, excluding management/qualified staff, fixed costs and various minor expenses are given in Table 4.6. Values are approximate and rounded to nearest R1000.

TABLE 4.6: Estimated Monthly Operating Costs of Boilers

Cost (R/month)	**Type of boiler (1000kg/hr steam)**		
	HFO	**Sasol gas**	**LPG**
Fuel	115000	187450	328900
Additional	11500	11500	11500

Total	126500	198950	296000

Source: Max Cruz, John Thomson, South Africa

4.6.3 Electrode Boilers

Fuel cost:

The efficiency of a well-maintained electrode boiler is typically 98%. The electrical power required to generate 1000kg/hr of steam at a pressure of 10 bar is 1000 x 2.78 / (0.98 x 3.6) = 788kW. The total energy consumed per month is 788 x 24 x 30 = 567360kWh for constant and continuous operation of the boiler. (In practice the maximum electricity demand over a 1-month period will most likely be higher than 788kW because the steam flow-rate will vary according to the steam profile of the boiler operation, and this will effectively increase the cost of the steam in the case of a maximum demand tariff.)

Steam costs are dependent on the applicable electricity tariff. The monthly electricity costs for continuous steam production at a rate of 1000kg/hr are as follows:

(1) Eskom Nightsave tariff

Demand charge (788kVA @ R46.26/kVA.mth)	R36425
Energy charge (567360kWh @ 8.3c/kWh)	R47090
Total:	R83515

(2) Eskom Megaflex tariff

Demand charge (788kVA @ R14.06/kVA.mth)	R 11079
Energy charge (567360kWh @14.21c/kWh)	R80621
Total:	R91700

(3) Eskom Miniflex tariff

Demand charge	nil

Energy charge (567360kWh @ 16.77c/kWh) R95146

Total: R95146

(4) Johannesburg Metro

Demand charge (788kVA @ R61.06/kVA.mth) R48119

Energy charge (567360kWh @ 11.07c/kWh) R62806

Total: R110925

Interruptible supply tariff (Eskom spot price) – An alternative electrical supply that is provided by Eskom, often suitable for operating an electrode boiler in cases where a standby boiler is available, is an interruptible supply with special pricing options. These options usually apply to large customers (MVA category). The cost of steam from a combination of electrode boiler operated under an Eskom interruptible or spot-price supply agreement and an HFO boiler (used only when the electricity supply is interrupted and during peak tariff and electrode boiler maintenance periods) depends on many variables including the amount of time that each boiler is required to operate over a given period. The system can also be employed for load levelling to reduce unavoidable costs to Eskom. Such supply agreements are usually region-specific and complex (http://www.ne.su.se/electric.com).

Additional costs:

The capital cost of an electrode boiler is usually less than that for a coal, gas or liquid-fuel boiler of similar capacity, especially in the case of small to medium-sized boilers. A typical 1000kg/hr electrode boiler supplied by John Thompson Africa or Steamers (Durban) costs about R149500 or about 30% of the cost of a similar size coal or liquid fuel boiler. The cost of a large HV-electrode boiler for steam production in the order of 50 tons/hr is likely to be well over R1m.

Boilers are automated and labour costs are low (much less than for a coal-fired boiler). Additional operating costs are regular maintenance, replacement of corroded electrodes, and chemicals for water treatment. These cost-figures are unavailable but considered to be relatively small in relation to the cost of electricity consumed. The most important additional (fixed) cost element is the infrastructure to provide the necessary electrical capacity (sub-station, transformers, HV-cables and/or switchgear). A small to medium-sized industrial installation is likely to cost more than twice the capital cost of the boiler because of infrastructure requirements. If insufficient external capacity exists, the cost of transformer/s, upgrading of cables, etc. that is incurred by Eskom or the local supply authority, is passed on to the consumer. For example, Durban Metro charges approx. R50/m for upgrading HV-cabling back to the sub-station, which may be some considerable distance from the customer's boiler location.

Table 4.7 shows a typical breakdown of costs for the installation of a small electrode steam boiler.

TABLE 4.7: Typical Cost Breakdown For Electrode Boiler Installation (1000kg/hr Steam Production)

Equipment	Cost estimate (R)
Electrode Boiler (incl. spare electrode head)	146050
Inside infrastructure (cabling, switchgear, etc)	128800
Outside infrastructure upgrade (HV-cable, etc)	172500
	447350

Source: C. Nicosia, Indus. Specialist, Distribution, Eskom, Durban

Note:

(1) Could increase significantly if a new transformer (11kV/380V) is needed.

An important consideration in using an electrode boiler for steam generation in an industrial application where electricity is also used for other purposes is the impact on maximum demand, and thus on the effective cost of electricity used. In the example given in par. 4.6, the effective unit cost of electricity, before installing an electrode boiler, was 31.4c/kWh. The electricity consumption of the boiler is given in par. 4.6.3(4). The result is an increase in load factor (from 42% to 67%) and a reduction of 25% in the effective unit cost of electricity, to 23.6c/kWh.

Electricity is usually a viable alternative to most other boiler fuels, excluding coal, except when a maximum demand tariff is applicable and the boiler is operated intermittently or with a low load factor (e.g. for 9 hours per day, 5 days per week). If steam demand is not continuous, a high boiler turndown is required which increases the effective kWh cost because the maximum demand charge will apply even during periods when the boiler is idle. Electrode boiler operation is most economical when large quantities of steam are required (using an HV electrode boiler) and a spot price tariff is applicable. A standby boiler is required in such cases.

Comparative estimates of the total monthly cost of operating an electrode boiler that produces 1000kg/hr of steam continuously, excluding management/qualified staff, fixed costs and various minor expenses are given in Table 4.8. Estimates are rounded to nearest R1000.

TABLE 4.8: Estimates of Monthly Operating Costs of Small Electrode Boiler for Various Electricity Tariffs

Cost (R/month)	**Nightsave**	**Megaflex**	**Miniflex**	**Joburg**
Electricity	84000	92000	96000	156000
Additional	10000	10000	10000	10000
Total	94000	102000	106000	166000

Source: C. Nicosia, Indus. Specialist, Distribution, Eskom, Durban

In the case of a maximum demand tariff, the electricity cost will increase if the boiler is operated at under full capacity due to a decrease in load factor.

4.6.4 Cost of Steam – PWV

Table 4.9 gives a summary of the comparative costs of steam based on the calculated monthly costs given in par. 4.6.3 above for various boiler fuels, in order of cost (PWV-area). In relative terms, coal is the cheapest energy source for steam production followed by electricity. LPG is the most costly energy source.

TABLE 4 9: Costs Of Steam (1000kg/hr) – PWV

Energy source	**Steam costs (c/kg)** **Fuel**	**Additional**	**Total**
Coal	2.71	3.99	6.7
Eskom electricity (Miniflex)	**10.66**	**1.59**	**12.6**
Metro electricity (Joburg)	15.32	1.59	16.9
Heavy Fuel Oil	**15.97**	**1.59**	**17.6**
Illuminating Paraffin	26.03	1.59	27.7
Coal gas (Sasol gas)	28.30	1.59	29.9
Diesel	33.38	1.59	34.9
Liquefied Petroleum Gas	45.67	1.59	47.3

Source: Max Cruz of John Thompson SA and C. Nicosia, Indus. Specialist, Distribution, Eskom, Durban

Note:

(1) Excludes cost of capital for boiler, infrastructure, ancillary equipment, qualified staff, water, water treatment chemicals, start-up fuel (if required) and other minor costs. An industrial coal-fired boiler is somewhat more expensive than a similar capacity oil or gas-fired boiler due to the need for coal-feeders and stoker equipment. Electrode boilers are less costly.

(2) Assumes constant steam demand. In practice steam flow-rate varies and costs will be higher, especially in case of electrode boilers operating on a maximum demand tariff.

(3) Unit steam costs will tend to decrease for higher steam production rates. In the case of coal, for instance, steam production of 10000kg/hr is estimated to cost about 3.7c/kg.

Based on the above **quantitative** and **qualitative** information it would appear that for the particular application studied (production of 1000kg/hr steam in the PWV area), coal is the least costly energy source notwithstanding several additional but unquantified costs. These are unlikely to increase the total cost above that of the nearest competing energy source, which is electricity. HFO has higher indirect costs compared to electricity, while IP and diesel are more costly fuels notwithstanding additional unquantified indirect costs. LPG, with associated pressurised tank-storage costs appears to be the most expensive alternative fuel (http://gisdevelopment .net).

4.6.5 Cost of Steam in Areas other than PWV

The only significant difference in the relative costs of steam for the various boiler fuels in areas other than the PWV is that for coal, HFO and electricity at the coast. It suffices to only compare the relative costs of steam production in Cape Town, where coal is most expensive and HFO the least expensive alternative fuels. Additional costs are similar to those estimated for the PWV.

(1) Coal-fired boiler

As given in par. 4.6.1, monthly coal consumption would be approximately 90 tons. At a delivered price of R442/ton in Cape Town, the monthly cost of coal for 1000kg/hr continuous steam production is as follows:

Fuel costs	R39847
Additional costs	R28750
Total:	R68587
Comparative cost of steam (@1000kg/hr):	9.5c/kg

(2) HFO-fired boiler

The quantity of HFO required for 1000kg/hr continuous steam production is 57600 litres/month - see Table 4.5. Priced at 175c/l the total monthly cost would be as follows:

Fuel costs	R100684
Additional costs	R11500

Total:	R112184
Comparative cost of steam (@1000kg/hr):	15.6c/kg

(3) Electrode boiler

For 1000kg/hr continuous steam production, the electrical requirement is 788KVA and 567360kWh/month - see par. 4.6.3. The monthly electricity cost would be as follows:

(a) Eskom Miniflex tariff (3% higher than PWV tariff)

Demand charge	nil
Energy charge (567360 @ 16.77c/kWh)	R95146
Sub-total:	R95146
Additional costs	R11500
Total	R106646
Comparative cost of steam (@1000kg/hr):	13.1c/kg

(b) Cape Town Metro bulk tariff

Demand charge (788kVA @ R40.59/kVA.mth)	R 31984
Energy charge (567360 @ 14.46c/kWh)	R 82040
Sub-total:	R114034
Additional costs	R 11500
Total:	R125524
Comparative cost of steam (@1000kg/hr):	17.5c/kg

Notwithstanding the fact that coal is more expensive in Cape Town than in most other region of South Africa due to high transportation costs, it is the least costly boiler fuel. The comparative costs of steam produced in Cape Town compared to the PWV area are about 43% more for coal, 11% less for HFO and 3% more for electricity.

4.7 PRICE OF CONTRACT STEAM

The price of steam manufactured by independent steam producers is typically in the range 7 – 13 c/kg for a 10-year agreement to supply 5 – 15 tons/hr of steam continuously (lower prices for higher consumption). This is usually obtained by a combination of electrode boiler operating on a low-cost (spot-price) interruptible electricity supply from Eskom and a standby boiler fired with liquid fuel (usually HFO), for use during periods of interruption in the electricity supply, peak-tariffs and maintenance (http://www.eia.doe.gov.com).

Contract steam usually includes all costs associated with steam production (fixed costs for electrical supply and control equipment, boilers and pipe-work, as well as variable costs such as labour, electricity, fuel, water, water-treatment, etc) and a profit margin. Compared to the costs given in Table 4.9, the above price appears to be an attractive alternative to own-steam production except for coal-fired boilers used for large steam production rates (>10 tons/hr) in the PWV area.

4.8 ELECTRODE BOILER POTENTIAL

Electrode boilers appear to be economically competitive –

- For relatively small steam requirements (100 – 300kg/hr, equivalent to 80 – 240kW$_e$), because electrical infrastructure upgrade costs are low.
- for replacing diesel-, paraffin- and LPG-fired boilers, because electricity is usually cheaper on an energy equivalent basis. HFO is marginal.
- For large steam volumes using an HV electrode boiler operated on a special Eskom interruptible supply tariff (spot price). A standby boiler, usually HFO-fired, is also necessary.

Electrode boilers are usually not economically competitive –

- When compared to coal-fired boilers in PWV and other areas where coal is relatively cheap due to close proximity to coalfields. More potential exists in Cape Town.
- When excessive infrastructure costs have to be incurred to supply the necessary electrical power to the boiler.
- When a maximum demand tariff is applicable and steam is required for less than about 12

hrs/day. This increases the effective cost of the electricity and the cost of the steam due to the low electrical load factor.

4.9 CONCLUSION

Different industrial boilers (coal, gas, liquid fuel and electric) were appraised in terms of cost, efficiency, ratings and various other factors (Chamber et al. 1979). The following table shows the results of calculations for a small to medium sized boiler in the PWV and at the coast. (Note: Eskom electricity = 100 in PWV). Coal-based steam was found to be the least costly, followed by electricity and then HFO. LPG is currently the most expensive energy source for steam production.

Table 4.10 Relative Cost of Steam Production

Energy source	*Relative cost of steam production*	
	PWV	*Coast*
Coal	*52*	*75*
Eskom Electricity	***100***	***102***
Metro electricity	*132*	*137*
HFO	***138***	***123***
Illuminating Paraffin	*216*	*202*
Coal gas	*234*	*234*
Diesel	*274*	*261*
LPG	*370*	*338*

Source: National Electricity Regulator and dept of Energy & Minerals

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CHAPTER 5

DEMAND SIDE MANAGEMENT

5.1 INTRODUCTION

Demand Side Management programmes are being implemented and promoted across the globe with the aim of reducing peak demand and promoting energy efficiency. The strategy embarked on by major energy suppliers rely on the voluntary participation whereby the participants are lured into subscribing to the initiative through elaborate funding schemes, soft loans and promises of substantial savings.

Most participants (hereinafter referred to as "the Energy Users") are oblivious in respect of the benefit to themselves, their energy supplier and the environment and it is often not willing to subscribe to the process. Participation should no longer be voluntary but should be regulated through regulation and become compulsory for especially the industrial and commercial sector. This will ensure the effective implementation of Demand Side Management initiatives and will provide the necessary structure to a currently hit-and-(often) miss strategy.

Demand-side management is a process relied upon by the major energy suppliers for substantial peak demand reduction, with the objective of promoting energy efficiency and joint control of energy demand. Over the world various initiatives to promote Demand-side management are being rolled out i.e. Eskom has introduced a 25 year plan which will enable them to implement energy efficiency measures and to a certain extent control of energy supply and in the United States billions of Dollars are spent annually in implementing more than 600 DSM programs.

Apart from the obvious benefit to the Energy Users and the Energy Suppliers, the effective implementation of Demand Side Management initiatives will also benefit the environment by limiting the carbon dioxide generated by the power stations which are released into the atmosphere.

5.2 METHODOLOGY

Information of Demand Side Management which includes energy efficiency and load shifting, DSM process and the DSM program utilized in the industrial/commercial sector was gathered through e-mails, telephone deliberations, faxed data and consultations with:

- **Tobie Nortjie: Eskom DSM**
- **Prof. LJ Grobbler: President of the Southern African Association for Energy Efficiency(SAEE)**
- **Tony Golding: Department of Energy and Minerals**
- **Prof. Ian Lane: Energy Cybernetics**
- **Dave Bekink: National Power**
- **Frans Rosseau: Customer Executive Northern Region**
- **D.L.W Kruger: SouthAfrica Association of ESCO's**
- **Francios Jonker: Process Control Superintendent Corobrik**

5.3 CURRENT IMPLEMENTATION

Most energy suppliers, including Eskom, rely on cost based incentives such as soft loans and shared savings to promote Demand-side management (Surtees 2003). The model is however costly and requires substantial administrative resources to sustain and the implementation thereof is often hampered by a bureaucratic ado.

Eskom has appointed a number of ESCO's (Energy Services Companies) who promote Demand Side Management initiatives to energy users with the primary driver being the savings associated with the implementation thereof. In the event of the energy user appointing the ESCO to represent it in submitting a Demand Side Management programme, the ESCO shall do an assessment and submit a proposal to Eskom. If the implementation criteria are met the ESCO shall assist the energy user in implementing the Demand Side Management programme and Eskom offers financial assistance for approved projects, which includes funding the capital expense and contributing **50% (energy efficiency) 100% (load shifting)** towards the project implementation cost.

The success of the implementation and promotion of Demand-side management process is mostly the result of incidental participation rather than deliberate enforcement. This gives the impression that energy suppliers are not committed to the process, which is regrettable, taking into consideration the commercial and environmental benefits. A more proactive approach rather than the current reactive approach may achieve more satisfying results.

5.4 PROCESS

To ensure that effective and successful implementation of a Demand-side management program (Gellings, Chamberlin 1993) and (Bjorkqvist 1996) identified a six-step process being the following:

- The establishment of a base case (Step 1)
- Construction and ranking of Demand-side management programs (step 2 – 4) including identifying demand-side management measure, maximum potential analysis and economic screening
- Implementation
- Evaluation

This process can be time consuming and often energy users may find it too cumbersome, which can result in the Demand-side management program not being implemented. The benefit however outweighs the inconvenience and energy users should be obliged to follow the necessary steps to implement a Demand-side program.

5.5 OBJECTIVE AND CHALLENGES

5.5.1 Objective

The load-shape changing objectives of Demand-side management consist inter *alia* of peak clipping, strategic load growth, load shifting and flexible load shape. This can only be achieved through the accumulation of accurate data, well designed programs accompanied by implementation strategies, which are flexible enough to adapt to ongoing demand side programs as more comprehensive data becomes available.

5.5.2 Challenges

As many energy users are oblivious as to the process of implementation and benefit of Demand-side program one might find that they are reluctant to embark on the process and regulating is therefore advisable. Many business people are so busy with running their businesses that spending time on discussing a Demand Side Management program is often deemed to be the same as discussing a new insurance package with a broker namely an unproductive waste of time.

Over and above the challenge of convincing energy users to subscribe to a Demand-side initiative, the growth in the commercial and industrial sectors as can be seen from the number of factories and office buildings that are erected annually makes the monitoring and control of the effective implementation of the Demand Side objectives of the energy suppliers almost impossible.

The time has come to structure the process and to ensure that participation is no longer voluntary but compulsory. It is also significant that the implementation shall no longer be an ad hoc affair but should be structured through due process and effectively targeting the market.

5.6 CLASSIFICATION

The large energy users can be divided in two distinct categories namely potential users where buildings/industries are still being erected and established users where buildings/industries have been completed. The established users can be divided into energy users that have not appointed an ESCO and who have not subscribed to a Demand Side Management program on the one hand and energy users that have appointed ESCO's and subscribed to a Demand Side Management Program on the other hand.

The approach to ensure the effective implementation of Demand Side Management in respect of these two categories should be different only in that one will be implemented on a proactive basis and the other on a reactive basis but participation should always be compulsory and implementation structured and controlled.

5.7 PROACTIVE APPROACH

5.7.1 Target Market

The pro-active measures can effectively be implemented in the development and building of facilities such as factories, shopping centres and office blocks, for large energy users which form part of the industrial and commercial sectors.

This can only be done effectively if the compliance thereof forms part of enforceable regulation or statutory stipulation, instead of voluntary recommendations and complicated financial models.

Although the suggestions contained in this document are not limited to the South African market it is especially relevant in South Africa as it is currently going through a boom period with regard to building and development. By regulating the demand-side programs through enforcing compliance through statute or regulation, it will be possible to expedite the meeting of the goals set out by the Demand Side Management 25 year plan as proposed by Eskom.

Although this chapter concentrates on the South African Energy market, the proposals contained herein are as applicable to other energy suppliers. Following these guidelines will expedite reaching the targets as set down by energy suppliers across the globe.

5.7.2 Pre-building Preparation

It is proposed that the installation of monitoring and verification equipment should form a compulsory part of equipment to be installed according to the building regulations in any new buildings to be erected. Just as a property developer is obliged to appoint an architect who must submit building plans for approval, he should also be obliged to appoint ESCO (Electricity Services Company) to advise him on the equipment to be installed as part of the compulsory compliance with DSM regulations. Building inspectors in conjunction with the appointed ESCO should ensure that the monitoring and verification equipment is installed incompliance with regulations just as such inspector ensures that the electrical and plumbing installations are done according to the submitted plans and regulations.

5.7.3 Monitoring and Verification Equipment

The equipment installed during the building process shall include but not be limited to meters compatible with remote meter reading software, which will enable the ESCO to accumulate the data necessary for the effective implementation of a Demand –side management program.

5.7.4 Post Building Data Collection

Subsequent to completion of the building process the ESCO shall assist the energy user in ensuring that the monitoring and verification equipment is properly commissioned so that the data necessary for the effective design and implementation of a Demand Side Management program.

The ESCO shall have a period of two months from date of completion of the building to file a Demand Side Management plan setting out the proposals; equipment required and estimated effect of the Demand Side Management Program.

5.7.5 Demand Side Management Program

Eskom will then have the option to evaluate the viability of the process and to approve the financing of certain capital expenditure, which will form part of the building cost including the capital expense required and the cost of implementation of the Demand Side Management program.

This is similar to the Environmental Impact Report to be filed by any property developer prior to a development being approved but shall be limited to the Demand-side management and shall be filed within two months after completion of the building process.

5.7.6 Bi-annual Audits

The implementation of the plan and re-evaluation of the effectiveness thereof should be the duty of the designated ESCO who shall be tasked with conducting an audit process and to report on Eskom on the outcome thereof bi-annually. Such audit report shall indicate the suggested measure, progress on the implementation of the Demand-side program, the success thereof as well as further recommendations.

5.7.7 Non Compliance

Failure to comply should result in penalties for the energy user and the ESCO. The stipulations of the regulation or statute should also provide Eskom or the energy supplier with a mandate to take alternative steps to ensure compliance with the proposed Demand Side Management plan in the event of the ESCO appointed by the energy user, failing to do so.

5.7.8 Benefit

This process will provide the energy user with the benefit of savings due to the efficiency of energy usage right from inception of his operations and shall also address the challenge convincing the energy user to subscribe to the Demand Side Management program.

Through the stringent regulation of the process from the moment of erecting the building the otherwise cumbersome and inept procedure of ensuring the implementation of the Demand Side Management program is sidestepped. The risk of not reaching all energy users is also reduced as no building can commence until proof of the appointment of the ESCO is filed and no building can be signed off by the building inspectors prior to ensuring that the monitoring and verification equipment has been installed.

5.8 REACTIVE APPROACH

5.8.1 Energy Users without ESCO's

5.8.1.1 Target market

Where buildings have already been erected and operations have already commenced or have been proceeding for a number of years, there are no other options but to regulate the implementation of the Demand-side management programs retroactively. This regulation must be done through statute but where that process is inappropriate through enforceable regulation.

The database of the energy users, which in the case of South Africa currently is Eskom, can be used to identify energy users that have not appointed an ESCO or subscribed to a Demand Side Management program. Such lists should be made available to ESCO's so that the necessary assistance can be rendered to energy users. Instead of the current nature of Demand-side management, which is descriptive, a prescriptive approach should be adopted.

5.8.1.2 Appointment of ESCO

All power users should be obliged to appoint an ESCO who shall eventually assist them in filing a comprehensive Demand-side management plan within a short period not exceeding 12 months from date of appointment.

5.8.1.3 Data collection

Prior to the filing of the Demand Side management plan it is however essential to accumulate certain data. This data can only be collected through approved monitoring and verification equipment which have to be installed.

The first task of the ESCO, subsequent to appointment, shall be to ensure that equipment is installed in accordance with industry standards. An undertaking must be sought from the energy user and the ESCO that such equipment shall be procured and installed within two months from date of appointment failing which Eskom shall be entitled to procure and install such equipment and recover the cost from either the ESCO or the energy user.

The ESCO must advise the client on the use of the monitoring and verification equipment and must ensure that sufficient data is collected to ensure the effective design and implementation of a Demand Side Management Plan.

5.8.1.4 Demand side management program

The data must be collected to support and effective Demand Side Management plan. In conjunction with the energy user the ESCO must submit within the twelve- month period a comprehensive proposal to Eskom or the energy supplier, for approval. Eskom or the energy supplier can then render financial assistance in respect of the capital expense and the implementation cost. Once the plan has been approved the ESCO shall be responsible to ensure that the plan is implemented within a prescribed period of time.

5.8.1.5 Bi-annual audits

Subsequently implementation of the Demand Side Management plan the usual audit process should be applied where the ESCO is obliged to report bi-annually on the progress and success of the implementation of the demand-side management program as well as further recommendations.

5.8.1.6 Non-compliance

The failure to comply with the regulations should carry a penalty and even suspension of an ESCO. Eskom or any energy supplier should also have the power to take corrective action to ensure that the Demand side management plan is implemented and maintained in the event of the ESCO or energy user failing to comply with the regulations set out herein.

5.8.2 Energy users with ESCO's

5.8.2.1 Target market

Where energy users have already appointed and implemented a Demand Side Management program one is met by the problem of the existing contracts which may exist between the ESCO and the energy user. These contracts and relationship should, after implementation and promulgation of the regulation, be regulated by the stipulations of such regulation or statute.

5.8.2.2 Bi-annual auditing

Although one is reluctant to interfere in the freedom to contract that each party has the regulation regarding auditing and reporting should with necessary alterations be applicable the energy users and ESCO's falling in this category.

5.8.2.3 Non-compliance

Failure to comply with the bi-annual audit process and ensuring that the Demand Side Management program is optimized and effectively implemented should carry penalties such as fines or even in certain circumstances suspension.

5.9 CONCLUSION

The only way in which the benefit of control and efficiency, which is a direct result of Demand-side management, can be achieved, is for the process and maybe even governing it by statute is the only responsible way forward, which should be embraced by the energy supply companies across the globe.

The time has come to take responsibility for the efficient energy consumption globally to optimize the benefit to the users, suppliers and probably most significantly the environment and this proposal will ensure that the joint responsibility is taken by the energy user, energy supplier as well as the ESCO.

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CHAPTER 6

REFLECTION AND GENERATION OF OPTIONS

6.1 BACKGROUND

This study compared the latest available energy prices in South Africa. Energy sources available to the industrial sector, namely coal, coal gas, diesel, illuminating paraffin, heavy fuel oil, liquefied petroleum gas and electricity, were compared in eight geographic areas. These are the inland areas PWV, Bloemfontein, Pietersburg and Nelspruit, and the coastal areas Cape Town, Durban, Port Elizabeth and Richards Bay.

As the energy cost is not the only factor influencing the total cost of using a particular energy source (Cleveland et al .1984), the objective for this study was also to evaluate energy sources on an effective cost basis, taking account of energy price as well as indirect costs and utilization efficiencies. The typical industrial application of steam generation was selected and the costs related to using various energy sources in this application evaluated.

Eskom (DSM) actions are consequently deliberate interventions in the Electricity Supply Industry (ESI) to change the configuration or magnitude of the load shape for the benefit of the national economy. For example, implementing specific electricity efficiency programmes (or load management programmes) can benefit the national economy and the environment if these programmes are cheaper to implement than building and operating equivalent supply- side capacity, i.e. construction of new Power Stations.

South African businesses can make significant savings through the efficient use of electricity. Eskom is sponsoring a DSM programme to help reduce demand for electricity at peak periods, which are from 7am to 10am and from 6pm to 8pm. Eskom DSM aims to reduce electricity demand during these periods, both by encouraging more efficient consumption during peak times and by moving demand to off-peak periods. Electricity efficiency can be implemented without affecting your business or your production levels.

6.2 ENERGY PRICES

TABLE 6.1: Comparative Energy Price by Region

COMPARATIVE ENERGY PRICES BY REGION (C/MJ) – JUNE 2005

Energy source	**Comparative energy price (c/MJ)**			
	PWV	**Durban**	**P. Elizabeth**	**Cape Town**
Coal	0.80	1.18	1.38	1.65
Diesel	10.4	10.05	8.38	10.05
IP	8.17	7.58	6.32	7.58
HFO	**5.01**	**4.38**	**3.65**	**4.38**
LPG (bulk supply)	14.01	12.63	12.24	12.65
Eskom electricity	**4.89**	**4.94**	**4.99**	**5.04**
Metro electricity	7.29	6.73	6.01	6.91

Energy source	**Comparative energy price (c/MJ)**			
	Bloemftn	**Nelspruit**	**Pietersburg**	**Richards Bay**
Coal	1.06	0.97	0.97	0.96
Diesel	10.50	10.51	10.62	10.26
IP	8.22	8.22	8.36	7.86
HFO	**5.13**	**5.13**	**5.30**	**4.38**
LPG (bulk)	14.01	14.24	11.87	13.81
Eskom electricity	**4.94**	**4.94**	**4.94**	**4.94**
Metro electricity	7.28	9.34	9.14	6.14

Note:

(1) Average price of road-delivered A-grade bituminous coal.
(2) Price is for electricity equiv. of ±186000GJ/yr
(3) Calculation based on 10MVA at 60% LF = ±186000GJ/yr.
(4) *Supplied by Johannesburg Metro.*

Source: Municipalities, Mcphail & Cullen Coal, Dept of Mineral & Energy

Prices to June 2005 were collected for the various fuel sources. Where possible pricing mechanisms and/or structure as well as price flexibility and negotiability are included in the study (Kaufman 1994).

The energy prices for June 2005 were then calculated on an energy equitable basis by converting the usual price units (e.g. c/kg, c/litre, c/kWh) to comparative prices expressed in c/MJ. These comparative energy prices (c/MJ) are given in Table 6.1 above. For electricity where several tariffs are available, the most suitable tariff for general industrial use was selected. The table 6.1 above gives the comparative energy prices for June 2005 in the eight study areas based on the assumptions made regarding power and energy requirements. Minor charges have been excluded.

6.3 DEMAND SIDE MANAGEMENT

The National Electricity Regulator (NER) and Department of Minerals and Energy (DME) have, through the White Paper on Energy Policy, revealed that they recognize the significance and the potential of energy efficiency and load management. It is in response to this, that Eskom leadership in its turn made a firm commitment to Demand Side Management (DSM) and to the targets set for energy efficiency in South Africa.

The Eskom DSM Department is expecting to play a leading role in Government's proposed National Energy Efficiency Alliance as coordinator of DSM and specifically Energy Efficiency initiatives. Eskom DSM already has the necessary expertise, skills and strategic positioning to be an effective vehicle for the implementation of these initiatives. This proposed role is in line with the government stance to draw stakeholders together and drive DSM projects by market initiatives that are centrally coordinated.

The Eskom DSM decision-making processes are based on the principles defined by the White Paper on Energy Policy relating to, amongst others, the restructuring and governance of the ESI, energy efficiency, the introduction of competition in the long term and the funding strategy of the Demand Side Management programme. Eskom offers financial assistance for approved load management projects designed to shift electricity consumption off-peak periods in order to reduce peak loads, which includes funding the capital expense and contributing **50% (energy efficiency) or 100% (load shifting)** towards the project implementation cost.

Benefits of DSM viz:

- Reducing during demand peak time
- Delaying the requirement for infrastructure capital investment
- Keep electricity cost down
- Customers can choose from a range of electricity efficient options to implement and benefit financially
- Supporting the macro-economic development of the economies through improved productivity

Benefits of Electricity Efficiency viz:

- Saving electricity means saving money
- Preservation of non-renewable resources
- Conserving the environment by reducing emissions and water consumption at Power Stations

Demand Side Management is the process whereby an electricity supplier influences the way electricity is utilized by customers. DSM means means the planning implementation, and monitoring of end-user's activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. The prime objective of DSM is proving constant, efficient use of electricity thus resulting in lesser amounts of electricity during peak times, thus managing the demand effectively. Eskom DSM as a Coordinating Agency should therefore have sufficient robustness to function within any restructured environment.

6.4 STEAM COST COMPARISON

To evaluate the various energy sources on an effective cost basis, taking account of energy price as well as indirect costs and utilization efficiencies, the typical industrial application of steam generation was selected (Tissot 1979).

In evaluating the total cost of using the various energy sources as opposed to comparing costs on a simple energy equitable basis, an analysis of energy cost as well as fixed and variable costs, utilization efficiencies and equipment associated with using these energy sources for steam production was undertaken. Different industrial boilers (coal, gas, liquid fuel and electric) were appraised in terms of cost, efficiency, ratings and various other factors. Results were calculated in terms of cost per unit of steam produced (Becker 1983).

Guidelines to determine the amount of steam that can be produced using different energy sources are: As a rule of thumb, a well-maintained coal-fired boiler (efficiency ±80%) produces 8kg steam per kg of coal; a liquid fuel-fired boiler (efficiency ±82%) produces 11-12kg steam per litre of fuel; and an electrode boiler (efficiency ±98%) produces 1.25kg steam per kWh.

Table 6.3 below shows the results of calculations for a small to medium sized boiler in the PWV and at the coast. Coal-based steam was found to be the least costly, followed by **electricity** and then **HFO**. LPG is currently the most expensive energy source for steam production.

TABLE 6.2: Relative Cost of Steam Production

RELATIVE COST OF STEAM PRODUCTION (Eskom electricity = 100 in PWV)

Energy source	**PWV**	**Coast**
Coal	52	75
Eskom Electricity	**100**	**102**
Metro electricity	132	137
HFO	**138**	**123**
Illuminating Paraffin	216	202

Coal gas	234	234
Diesel	274	**261**
LPG	370	338

Source: Municipalities, Mcphail & Cullen Coal, Dept of Mineral & Energy

The potential for electrode boilers can be summarised as follows:

Electrode boilers appear to be economically competitive -

- For relatively small steam requirements (100 – 300kg/hr, equivalent to 80 – 240kW$_e$), because electrical infrastructure upgrade costs are low.
- For replacing diesel-, paraffin- and LPG-fired boilers, because electricity is usually cheaper on an energy equivalent basis. **HFO is marginal.**
- For large steam volumes using an HV electrode boiler operated on a special Eskom interruptible supply tariff (spot price). A standby boiler, usually HFO-fired, is also necessary.

Electrode boilers are usually not economically competitive -

- When compared to coal-fired boilers in PWV and other areas where coal is relatively cheap due to close proximity to coalfields. More potential exists in Cape Town.
- When excessive infrastructure costs have to be incurred to supply the necessary electrical power to the boiler.
- When a maximum demand tariff is applicable and steam is required for less than about 12 hrs/day. This increases the effective cost of the electricity and the cost of the steam due to the low electrical load factor.

6.5 CONCLUSION

This study concluded that on an **energy-equitable basis**, the price of **Eskom electricity** is lower than that of all other energy sources except coal, which is associated with additional indirect costs and about the same as the **HFO** price in coastal areas.

It is expected that industrial demand for electricity will continue to grow in the future, both for new and existing applications where switching from petroleum-based fuels used in industrial heating applications are technically feasible and economically viable. This is because of the relatively low current price of electricity and the fact that average prices of all other energy sources have increased significantly in recent years, with increases well above the inflation rate (Stigler 1971). Eskom electricity tariffs, in contrast, have decreased in real terms.

The most significant issue from an industrial consumer perspective is the relative cost associated with using one energy source compared to another, per unit of production (Owen 1970). A detailed energy-cost analysis should include all cost factors (direct and indirect), such as the fixed and variable costs associated with new equipment or the adaptation of existing equipment, energy storage (in the case of coal, liquid fuels and LPG), materials handling and ash disposal (coal), labour, prevention of environmental pollution. Utilization efficiency, power requirements and time-of-use criteria also have to be taken into consideration (Jochem & Gruber 1990). Energy cost comparisons (in contrast to price comparisons) can only be made on a user-specific basis.

This study provides a good reference to energy prices in the different areas. One must however keep in mind that energy prices are continuously changing thus making any data outdated as area specific energy data (not national averages) is generally difficult to accurately obtain and track.

The following general conclusions on an energy equivalent basis apply to all regions studied, subject to the given assumptions (which are based on a relatively high industrial energy demand):

- Coal is the least expensive energy source.
- The second least expensive energy source is Eskom electricity, which is priced about the same as HFO and averages 4 times the price of coal.
- Coal gas, where available, is priced about the same as Metro electricity.
- Metro electricity is less costly than IP except in Nelspruit and Pietersburg.
- Diesel is the second most expensive fuel.
- LPG is the most costly energy source, averaging 10 times the coal price.

6.6 OPTION 1

Use the existing boiler with coal as the energy source, however with this option, one has to pursue and exploits the local market. In order to sustain a competitive edge and sustain a positive balance sheet in terms of profitability, the management and the director of the organization will have to locate solutions to the current problems and rectify significant issues listed below.

6.6.1 Justification of option 1

- The coal-fired boiler proved very labour intensive.
- For the past 12 years the Inca Lime had to employ a team of attendants to stoke the boiler, maintain coal levels, monitor operation and dispose of ash
- Delays in coal delivery resulted in crisis management.
- The boiler took up a large area of floor space.
- Heat generated by the boiler, together with fumes and high noise level created uncomfortable working condition.
- Maintenance costs of the boiler are exorbitant.
- The boiler had to start 12 hrs prior to full steam pressure requirement.

6.7 OPTION 2

Relocate the plant to a coastal area, using HFO as an energy source. HFO prices are not regulated and there is no common list of prices for different regions as is the case for most other petroleum-based fuels. Consequently, the individual oil companies may have different prices at different times. The HFO information given below is nevertheless considered to be indicative of prevailing prices and market conditions in the various study areas.

Although most oil companies with coastal refineries can supply to inland customers, the major supplier in these areas is Sasol, from the Natref oil refinery at Sasolburg and the oil-from-coal plants at Secunda. Other companies would normally purchase product from Sasol to supply such customers or rail the product from the Durban refineries (Sapref and Enref).

6.7.1 Justification of options 2

- Comparative prices for HFO at the coast and in the PWV area for bulk deliveries are given in Table 6.4 below.

TABLE 6.3: Prices of Heavy Fuel Oil June 2005

Area	**List price (c/l)**	**Comparative price (c/MJ)**
Coast:		
Durban	**182**	4.38
Richards Bay	**182**	4.38
Port Elizabeth	**182**	4.38
Cape Town	**182**	4.38
Inland:		
PWV	**208**	5.01
Bloemfontein	**214**	5.14
Nelspruit	**214**	5.14
Pietersburg	**220**	5.30

Source: Caltex Oil (S.A.) (Pty) Ltd

Note:

(1) *Actual prices are volume dependent and may be above or below the list price (the capital cost of tank storage facilities and associated equipment installed by the Oil Company at the customer's premises may sometimes be recovered by way of a higher fuel price).*

(2) *Based on gross calorific value of 41.6MJ/l.*

(3) *Prices can vary by as much as 20%. As an example, Engen supplies Waxy-12 HFO, delivered ex Sasolburg to a brewery in Centurion, at a price of 250c/l for a volume of about 30 tons/month.*

6.8 OPTION 3

Utilize a dual fuel system in conjunction with Eskom's DSM initiative. Change the energy source from coal to electric and heavy fuel oil. Electricity prices are based on tariffs and charges determined by Eskom, as approved by the National Electricity Regulator. VAT is excluded in all cases.

The system comprises two fuel sources:

- ✓ Electricity as a primary system (Electrode Boiler)
- ✓ Heavy fuel oil as a secondary source (HFO Boiler)

The system is controlled using a radio signal that switches the electrode boiler off and your backup fuel boiler (HFO) on during Eskom's peak load conditions, between 7h00 - 10h00 and 18h00 – 20h00 and typically during the winter months. When the peak passes, a second signal is sent out switching your system back to the electric mode. If for any reason you require additional steam using your secondary fuel source for more than the minimum number of hours, you have this flexibility.

This is categorically a DSM opportunity in terms of load management / control systems in conjunction with dynamic pricing signals. Additionally this project is designed to shift electricity consumption to off-peak periods in order to reduce loads. Eskom DSM will provide 100% capital cost to procure the dual fuel boiler system, provided that the customer signs a DSM agreement with Eskom which includes:

- ➢ Committed MW reduction
- ➢ Penalties for non-conformance
- ➢ Asset ownership
- ➢ Maintenance of equipment
- ➢ Insurance

And the project must be:

- Sustainable
- Economically justifiable
- Minimum energy saving of 500kW

On peak days during the winter months, the demand for electricity is the highest. More resources and equipment must be utilized to generate the required capacity and this causes increased electricity costs. Installing Dual Fuel systems can alleviate these costs. Additionally the customer will realize immediate and future savings by reducing the demand for electricity by being energy efficient. The customer will receive additional savings by keeping electricity generation and transmission costs down through more economical load management. This option will certainly assist the environment, by reducing our dependence on fossil fuel, specifically coal for steam generating.

6.8.1 Justification of options 3

- Tariff for industrial electricity is Megaflex, Miniflex and Nightsave
- The Megaflex tariff is for customers with supplies of 1MVA and above.

  The connection fee is R22 807, 02. Service charge: R63.73/day, Admin charge: R36.77/day, Network access charge: R6.41 and Maximum demand charge (only in peak and standard time-of-use periods): R12.87/kVA.month (during high-demand months June – August) and R7.59/kVA.month (during low-demand months September – May). The active energy charge varies between 8, 15 – 56,56c/kWh (peak time-of-use, June – August) and 7, 07 – 16, 07 c/kWh (off-peak time-of-use, September – May).

  Reactive energy is charged at 2.85c/kvarh supplied in excess of 30% (0.96 power factor) of kWh recorded during peak and standard periods. Monthly rental, voltage discounts and transmission surcharges are calculated as a percentage of networks demand except that in the case of monthly rental, a rate of 1.81c/kWh of peak period active energy consumption is charged when the maximum charge is applicable.

6.9 OPTION RECOMMENDED

Given the time frame, financial impact, human issues, condition of existing equipment and the problem i.e. coal as a source of energy is polluting the end product and Eskom's supply capacity; the director has decided to pursue option three namely a dual fuel system, which incorporates an electrode and a HFO boiler, subsequent to recommendation and deliberation with the author. **Option three**, which is viable and feasible, is to be implemented over a period of 12 months. (See Implementation Guidelines).

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CHAPTER 7

IMPLEMENTATION GUIDELINES

7.1 SYMTEMATIC APPROACH FOR AN ELECTRIC BOILER INSTALLATION

7.1.1 Electrode Boilers

The efficiency of a well-maintained electrode boiler is typically 98%.

The main advantages of electrode boilers are:

- Less capital cost than other boiler types
- Very high heat transfer efficiency
- Short start-up period
- Fully automatic
- Compact size
- No fire risk
- No pollution
- No boiler-house required
- No fuel storage required

Rationalising the need for development and the future progress requires a co-operative approach that will involve all stakeholders at various stages of the planning and implementation from inception of this project. The activities are as follows.

7.1.2 Action 1

Install a measuring instrument, which is left on site for a period of ten days to record data of the existing coal boiler (See Appendix F). The data will be downloaded and analysed by the student in order to ascertain a steam load profile and sizing of an appropriate electrode boiler.

7.1.3 Action 2

Steam cost study information sheet has to be filled in by Inca Lime. This information will assist the author and boiler consultants in calculating the cost of steam for the specific equipment. This will therefore enable Inca Lime to make a well-informed decision. (See Appendix B)

7.1.4 Action 3

The student will have to prepare a presentation (See Appendix D), which would incorporate the technical specifications, calculation of steam per ton as well as the comparison of the existing boiler with an electrode boiler. (See Appendix E).

7.1.5 Action 4

Once the electrode boiler capacity has been established, quotations are required by at least three manufacturers in order to ascertain the best possible price, quality and service.

7.1.6 Action 5

Inca Lime will complete an application form for electricity to be installed on site. Subsequent to the information being captured on the Eskom database, the author will work closely with department supervisors to ensure that the process is expedited through the various divisions within Eskom.

7.1.7 Action 6

The author and the pricing managers will compile tariff comparisons to identify the most cost-effective tariff applicable for Inca Lime and ensure that the necessary documentation is completed.

7.1.8 Action 7

The author will work closely with suppliers and Eskom to ensure that the project is on line with target dates and commissioned correctly. Customer service visits are conducted to ensure feedback (See Appendix C).

7.2 REACTION VISIT ACTION PLAN

Three months subsequent to commissioning of the electrode boiler the author will visit Inca Lime in order to ensure that the customer is using the electrical energy efficiently. Additional the author ensures that the customer receives cognisance that demand side management is the way forward in conjunction with Eskom's time-of-use tariffs.

The term “demand side management” was first used in the United States in the early 1980’s to describe the **planning and implementation** of utility activities designed to influence the time, pattern and / or the amount of electricity demand in ways that would increase customer satisfaction and co-incidentally produce desired changes in the utility’s load shape (Gelling et al. 1998).

Time-of-use tariff offered by Eskom to the industrial sector has three time periods namely peak, standard and off-peak. The peak times are from 07h00 hrs to 10h00 hrs and from 18h00 hrs to 20h00 hrs. The standards times are from 10h00 hrs to 18h00 hrs and from 20h00 hrs to 22h00 hrs. The off-peak times are from 22h00 hrs to 06h00 hrs. The price of electrical energy during off-peak and standard is much cheaper as compared to peak periods.

Therefore, the author will ensure that the customer will exploit Eskom's time of use tariffs, by shedding load or consuming the bulk of electrical energy during Eskom’s specified standard and off-peak periods. This will therefore lead to considerable saving in the cost of electrical energy.

7.3 THE STRATEGIC PROCESS FOR THE INSTALLATION IS AS FOLLOWS:

Action	Responsibility	Timeline	Outcome Feedback
1. Financial Planning			
• Engage services of an Accountant	Director	Immediate	completed
2. Ground Work			
• Energy audit	Industrelek	July 05	completed
• Install Netlogger (steam profiles)	Industrelek	July 05	completed
• Sizing of Electrode boiler	EB Steam	Aug 05	completed
• Boiler costs presentation	EB Steam/John Thomson Boilers	Aug 05	completed
3. Application for Electricity			
• Formal application.	Director	Sep 05	In progress
• Survey of infrastructure	Eskom - Survey	Oct 05	
• Feasibility study (network)	Eskom - Project Manager	Oct 05	
• Sub-station settings	Eskom – Plant	Ongoing	
4. Electricity Pricing			
• Tariff comparison. • Electricity contract	Eskom Pricing Manager	Nov 05	
5. Way forward			
• Commissioning process	EBSteam/John Thomson Boilers	Feb 06	
• Quality assurance systems	Director/ EB Steam	Dec 05	
• Train according to plan	Director	Feb 06 – Jun 06	

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8. BIBLIOGRAPHY

Adams, F. G & Miovic, P. 1968. On relative fuel efficiency and the output elasticity of energy consumption in Western Europe. Journal of Industrial Economics, 17: 41-56.

Allesio B. 1981. Energy & Society, Mcgraw Hill , New York

Andersson, B. 1993. A search cost approach to energy efficiency barriers, Proceedings of the Int. Conference. ECEEE Summer Study: The Energy Challenge for Europe, Vol. 2, pp. 3-9, Jun. 1-5, Rungstedgård, Denmark, The European Council for an Energy-efficient Economy, Oslo, Norway.

Ayres, R. U., Ayres, L. W. & Martiñas, K. 1996. Eco-thermodynamics: Exergy and life cycle analysis. INSEAD, Center for the Management of Environmental Resources. Working Paper 96/04/.

Becker, G.S. 1983. " A Theory of Competition Among Pressure Groups for Political Influence," Quarterlt journal of Economics, 98, (p.371-400).

Berndt, E. R. 1978. Aggregate energy, efficiency, and productivity measurement. Annual Review of Energy, 3: 225-273.

Bodlund, B. et al., 1989. "The Challenge of Choices: Technology Options for the Swedish Electricity Sector", In T. B. Johansson et al. (eds.) Electricity: Efficient End-use and New Generation Technologies, and their Planning Implications, Lund University Press, Lund.

Braithwait, S. D. 1994. Three Biases in Cost efficiency Tests of Utility Energy Efficiency Programs, Energy Journal, Vol. 15:1, (p. 95-120).

Bullard, C. W., Penner, P. S. & Pilati, D. A. 1978. Net energy analysis: a handbook for combining process and input-output analysis. Resources and Energy, 1: 267-313.

Chambers, R. S., Herendeen, R. A., Joyce, J. J. & Penner, P. S. 1979. Gasohol: does it or doesn't it provide positive net energy? Science, 206: 789-795.

Chapman, P. F. & Roberts, F. 1983. Metal Resources and Energy. Butterworths, London.

Cleveland, C. J., Costanza, R., Hall, C. A. S. and Kaufmann, R. 1984. Energy and the U. S. economy: a biophysical perspective. Science, 255: 890-897.

Devine, W. D., 1986. Historical perspective on electrification in manufacturing. In: Schurr, S. H. and Sonenblum, S. (Editor), Electric Power Research Institute, Electricity Use, Productive Efficiency and Economic growth, (p. 131-164).

Elmberg A. 1993, Action plan for energy efficiency, Göteborg Energi AB, Göteborg.

Eskom tariff hand book 2004-2005

Finon D. 1974. Optimisation model for the French energy sector, Energy Policy, (Vol. 2:2, p. 136-151), 1974 Freeman S. D., P. Baldwin, M. Canfield Jr., S.

Carhart, J. Davidson, J. Dunkerley, C. Eddy, K. Gillman, A. Makhijani, K. Saulter, D. Sheridan, R. Williams, A Time to Choose, Ballinger Cambridge, U.S.

Gellings C. W., Chamberlin J. H. 1998. Demand-side Management: Concepts and Methods, 2nd ed., The Fairmont Press, Inc., US. 1993a Goldemberg J., T. B.

Johansson, A. K. N. Reddy. R. H. Williams, Energy for a Sustainable World, Wiley Eastern Limited, India.

Hall C. A. S., C. J. Cleveland, & R. K. Kaufmann. 1986. Energy and Resource Quality: The Ecology of the Economic Process, Wiley Interscience, New York.

Hannon, B. 1973. The Structure of Ecosystems. Journal of Theoretical Biology, 41: 535-546.

Hasset K. A., G. E. Metcalf. 1993. Energy Conservation Investment: Do consumers discount the future correctly? Energy Policy, (p. 710-716).

Hirst E., R. Cavanagh, P. Miller.1996. The future of DSM in a restructured U.S. electricity industry, Energy Policy, Vol. 24, No. 4, (P. 303-315).

Hoffman K. C. 1974. A unified framework for energy system planning, in: Energy Modelling, IPC Science and Technology Press, England.

Hourcade J. C., T. Richels, J. Robinson, W. Chandler, O. Davidson, J. Edmonds, D. Finon. 1996. Estimating the Cost of Mitigating Greenhouse Gases, in J. P. Bruce, H. Lee, E. F. Haites (eds.), Climate Change 1995: Economic and Social Dimensions of Climate Change, Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change, (p. 263-296), Cambridge University Press, U.S.,

Höwing F., M & Strid E. 1995., Energy Use on New Terms (in Swedish, Gothenburg University.

Huettner, D. 1976. "Cogeneration and Decentralized Electricity Production". London, England, (p. 104–151)

Ingham A., J Maw, A. Ulph, 1991., "Testing for Barriers to Energy Conservation -- an Application of the Vintage Model," The Energy Journal, Vol. 12, No. 4.

Jochem E. & E. Gruber, "Obstacles to Rational Electricity Use and Measures to Alleviate Them," Energy Policy, Vol. 18, No. 4, (p. 340-350).

Jorgensen, D. W. and Griliches, Z. 1967. The explanation of productivity change. Review of Economic Studies, 34: 249-282.

Jorgensen, D. W. 1986. The role of energy in productivity growth. In: Schurr, S. H. and Sonenblum, S. (Editor), Electric Power Research Institute, Electricity Use, Productive Efficiency and Economic growth, (p. 43-92).

Joskow, P. L & Marron, D. 1993. What Does Utility-Subsidised Energy Efficiency Really Cost? Science, Vol. 260. (P. 281).

Kaufmann, R. K. 1994. The relation between marginal product and price in U.S. energy markets. Energy Economics, 16: 145-158.

Keating K. M. 1996. What roles for utility sponsored DSM in a competitive environment, Energy Policy, Vol. 24, No. 4, (p. 317-321).

Kraft J & A. Kraft .1978. On the relationship between energy and GNP, Journal of Energy and Development 3, 401-403.

Landon, J.H. 1973. " Pricing in Combined Gas AND Electric Utilities: a second look", Antitrust Bulletin, (p. 83-98).

Leach G., C. Lewis, A. van Buren, F. Romig, and G. Foley. 1997. A low energy strategy for the United Kingdom, Science Reviews Ltd., London.

Levine M. D., J. G. Koomey, L. Price, H. Geller, S. Nadel. 1995. Electricity End-Use Efficiency: Experience with Technologies, Markets, and Policies Throughout the World, Energy, Vol. 10:1, pp. 37-61.

Lovins A. 1990. Four Revolutions in Electric Efficiency, Contemporary Policy Issues, Vol. 8, No. 3, pp. 122-141.

Lovins A. 1996. Negawatts: Twelve transitions, eight improvements and one distraction, Energy Policy, Vol. 24, No. 4, pp. 331-343.

Manne A. S., & Wene. 1992. MARKAL-MACRO: A linked model for energy-economy analysis, BNL-47161, Department of Applied Science, Brookhaven National Laboratories, Upton, N.Y., USA.

Marcuse W., L. Bodin, E. Cherniavsky, Y. Sanborn. 1976. A dynamic time dependent model for the analysis of alternative energy policies., in: K. B. Haley (ed.), Operational Research 1975, North Holland, Amsterdam.

Meyer-Abich K. M., C. F. Von Weizsäcker. 1979. Energieeinsparing als neue Energiequelle: Wirtschaftspolitische Möglichkeiten und alternative Technologien, Carl Hanser Verlag, Germany.

Martinez-Alier, J., 1987. Ecological Economics. Basil Blackwell, Oxford, (p. 286).

Miller P. M. 1993. Letter, Science Vol. 261, pp. 970-971.

Mitchell, E. J., 1974. U.S. Energy Policy: A Primer. American Enterprise Institute for Public Policy Research, Washington, D.C..

Nadel S. 1990. Lessons Learned: A Review of Utility Experience with Conservation and Load Management Programs for Commercial and Industrial Customers, American Council for and Energy-Efficient Economy, Washington DC.

Nadel S., H. Geller. 1996. Utility DSM: What have we learned? Where are we going?, Energy Policy, Vol. 24, No. 4, pp. 289-302.

Nadel S. M., M. W. Reid, D. R. Wolcott (eds.) 1992. Regulatory Incentives for Demand-Side Management, American Council for an Energy-Efficient Economy, U.S. Odum, H. T. 1957. Tropic structure and productivity of Silver Springs, Florida. Ecological Monographs, 27: 55-112.

Odum, H. T., 1971. Environment, Power and Society. Wiley-Interscience, New York.

Olerup B. 1994. Efficient Electricity in Stockholm, Energy Sources, Vol. 16, (pp. 209-227).

Owen, B. M. 1970. " Monopoly Pricing in Combined Gas and Electric Utilities," Antitrust Bulletin, (p. 713-726).

Peet et al. 1989. " World Energy Strategies: Facts, Issues and Options, Friends of the Earth," San Francisco, (p. 240)

Peltzman, S. 1976. " Towards a More General Theory of Regulation," Journal of Law and Economics, (p.211-240).

Risling A.& P. Steen. 1993. The Self-Organising Energy Enterprise (in Swedish), Nuke, Stockholm.

Rosenberg, N. 1998. The role of electricity in industrial development. The Energy Journal, 19: 7- 24.

Schurr, S. and Netschert, B., 1960. Energy and the American Economy, 1850-1975. Johns Hopkins University Press, Baltimore.

Steen P., T. B. Johansson, R. Fredriksson, E. Bogren, Energy. 1982. - To what and how much (in Swedish), Liber, Stockholm.

Stigler, G. J. 1971. " The Theory of Economic Regulation," Bell Journal of Economics, (p. 3-21).

Sutherland R. J. 1996. The economics of energy conservation policy, Energy Policy, Vol. 24, No. 4, pp. 361-370.

The Swedish council of the realm, On improvement of stoves (in Swedish), January 27th, 1767.

The Swedish Government, Bill to the Swedish parliament, Energihushållning m.m. (in Swedish), Prop. 1975:30, 1975

The Swedish Government, Bill to the Swedish parliament, Energisparplan för befintlig bebyggelse. (in Swedish), Prop. 1977/78:76. 1977

Turvey R., D. Andersson. 1977. Electricity Economics: Essays and Case Studies, The International Bank for Reconstruction and Development, US.

United Nations Conference on Environment and Development, Rio de Janeiro, 1992

US Department of Energy, 1990. U.S. Oil and Gas Reserves by Year of Field Discovery, DOE/EIA-0534.

Vine E. L., H. Misuriello, M. E. Hopkins, 1994 A Research Agenda for Demand-Side Management Impact Measurement, Energy, Vol. 19:11, (pp. 1103-1111), World Commission on Environment and Development.

Webb, M. and Pearce, D. 1975. The economics of energy analysis. Energy Policy, 3: 318-331.

Wene, C & B, Rydén. 1988. A comprehensive energy model in the municipal energy planning process, European Journal of Operational Research, Vol. 33:2, (pp. 212-222).

Wilson, D.& J, Swisher. 1993. Exploring the gap: Top-down versus bottom-up analyses of the cost of mitigation global warming. Energy Policy, 21:3, (pp.249-263).

Internet websites

http://www.isr.gov/coal.com, "Performance Improvement at Banshan Coal Fired Power Plant," Andrew Ban, April 2000.

http://www.ne.su.se/electric.com, "Electricity spot Price Dynamics," Johan Gran, Nov 2001.

http://www.gisdevelopment.net, "The use of Partial Quantitative Information with Qualitative reasoning," Jared Daniel Berleant, 1991.

http://www.eia.doe.gov.com, "International Energy Outlook," Linda. E. Doman, 2002.

http://www.dme.gov.za, "Department of Mineral & Energy – History of Price & Price Elements," May 2002.

http://bridge.berkeley.edu/pdfs/biogasse_India_report.pdf)

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APPENDIX A

CALORIFIC VALUES OF ENERGY SOURCES

Energy source	Calorific value	Units f c.v.	Density (kg/litre)
Electricity	3.6	MJ/kWh	-
Coal			
Grade A	>28.5	MJ/kg	-
Grade B	27.5 – 28.5	MJ/kg	-
Grade C	26.5 – 27.5	MJ/kg	
Grade D	25.5 – 26.5	MJ/kg	-
Electricity (bituminous)	20.7	MJ/kg	-
Synfuels (bituminous)	26.8	MJ/kg	-
Industry (anthracite)	31.1	MJ/kg	-
Industry (bituminous)	26.8	MJ/kg	
Metallurgical (anthracite)	32.1	MJ/kg	-
Metallurgical (bituminous)	29.8	MJ/kg	-
Household (anthracite)	29.4	MJ/kg	-
Household (bituminous)	27.3	MJ/kg	-
Coal gas			-
Sasol-gas (hydrogen rich)	18.9	MJ/m^3	-
Sasol-gas (methane rich)	33.9	MJ/m^3	-
Diesel	38.1	MJ/l	0.84
Illuminating Paraffin (IP)	37.0	MJ/l	0.79
Heavy Fuel Oil (HFO)	41.6	MJ/l	0.98
Liquefied Petroleum Gas (LPG)	49.6	MJ/kg	0.54
Petrol	34.2	MJ/l	0.72
Natural gas	41.0	MJ/m^3	-
Wood (dry basis)	17.0	MJ/kg	-
Bagasse (wet basis)	7.0	MJ/kg	

Note:

Gross calorific value.

By definition, 1 kW = 1 kJ/sec, thus 1kWh = 3.6 MJ.

The calorific values for coal used in the main consumption sectors are for 1997 and were determined on an air-dry basis (Source: Minerals Bureau).

APPENDIX B

STEAM COST STUDY – INFORMATION SHEET

1. **Boiler Performance Parameters**

1.1. Operating hrs (hrs/day)
(days/week)
(weeks/yr)

1.2. Operating Absolute Pressure (kPa)
1.3. Feedwater Temperature (°C)
1.4. Condensate Return (%) and Temp (C)
1.5. Fuel Calorific Value (MJ/kg or MJ/lt)

2. **Annual Steam Production (if records exist) (tons/yr)**

3. **Coal Cost/HFO Cost**

    3.1 Cost of coal (R/Ton) or HFO (R/l)
    3.2 Annual Volume of Coal/HFO purchased.

4. **Ash Disposal Cost (R/yr)**

5. **Water Cost**

    5.1 Water price (R/kl)
    5.2 Effluent charges (R/kl)
    5.3 Sewerage charges (R/kl)
    5.4 Condensate Return (%)
    5.5 Blowdown/Waste (%)

6. **Chemical Costs (R/yr)**

7. **Electricity (if records exist) (R/yr)**

8. **Direct Labour Cost**

    8.1 Number of boiler operators and assistants
    8.2 Boiler operator and assistant salary (R/yr)
    8.3 Overtime hours of each (hrs/yr)
    8.4 Overtime rate of each (r/hr)
    8.5 Shift allowance of each (%)
    8.6 Annual bonus of each (%)
    8.7 Company contributions (%)

9. Indirect Labour Cost

9.1 Number of Supervisors, fitters and semi skilled persons
9.2 Approximate time spent on boiler house maintenance
9.3 Salaries of supervisors, fitters and semi skilled persons

10. Overhead Contribution

10.1Estimated time and cost of management supervision (plant engineer, engineering manager etc)
10.2Administrative costs (clerks, accountants, etc)

11. Capital Costs

11.1Depreciation and interest on Capital (R/yr.)

12. Maintenance

12.1General maintenance costs on boiler house (R/yr.)

13. Insurance

13.1Annual Insurance cost on boiler house.

14. Working Capital Costs

14.1Average HFO/Coal stock (R/yr)
14.2 Cost of capital (%)

15. Cost of Capital Replacement

HISTORICAL MAINTENANCE CHECK SHEET

BOILER HOUSE:			DATE OF LAST ACTION				
		Fuel (e.g. coal) Model (yr.) Capacity (ton/hr)	BLR #1	BLR #2	BLR #3	BLR #4	BLR #5
PART	ACTION	LIFESPAN (YRS)					
Shell	REPLACE	30					
Chimney & Ducting	REPLACE	20					
ID Fan	REPLACE	20					
Stoker/Burner	REPLACE	15					
Grit Arresters	REPLACE	12					

	Hotwell	REPLACE	10					
	Controls, Panel	REPLACE	10					
	Insulation, Cladding	REPLACE	10					
	Softeners	REPLACE	10					
	Tubes	REPLACE	10					
	Valves & Fittings	REPLACE	15					
	Pump	REPLACE	8					
	Stoker/Burner	REBUILD	5					
	ID Fan, Rotating Parts	REPLACE	5					
	Pump	REBUILD	2					

16. Other Costs to be considered: (Might have some figures)

16.1Environmental Impact
16.2Consequential losses of
    16.2.1 Production
    16.2.2 Sales
    16.2.3 Labour

APPENDIX C

LETTER

Inca Lime.
PO Box 3001,
Dendron
Polokwane
South Africa

Customer Service
Northern Region

90 Hans van Rensburg
Pietersburg
0700

Attention: Eskom - Industrelek

Dear Sir

FEASIBILITY STUDY OF ELECTRODE BOILER

Thank you for the proposal given to me on the feasibility study of the electrical boiler. This proposal with all the comments made on the coal fired boiler, and installation of our own electrical boiler, assisted the management team in make a well informed decision on which route to follow with regard steam supply.

The options that were under consideration / discussion were:

1. Coal fire boiler
2. Implementation of a dual fuel System (Electrode & HFO Boiler)

With the discussions and the comparative study between all options, which was presented to us by Lenny Chetty has assist in the decision making with regard to purchasing a dual fuel system through the DSM programme.

Thank you for all your time and effort spend on this study.

Brian Jennsen
Plant Engineering Manager

APPENDIX D

PROPOSAL FOR ELECTRODE BOLIER

Inca Lima South Africa (Pty) Ltd

Attention: Brian Jennsen

Date	**Enquiries**
23 August, 2005	Lenny Chetty Cell: 0828768807

FEASIBILITY STUDY OF ELECTRODE BOILER

On request by Brian Jennsen, Industrelek has been given the opportunity to test the feasibility of the installation of an Electrode Boiler. This would be done in comparison with the existing coal boiler utilised by Inca Lime.

If **Inca Lime SA** were to consider an Electrode Boiler, the cost of producing steam would be much higher than the existing steam boiler. The cost is estimated at approximately **R188.00 per ton** of steam during the **high demand period** and approximately **R149.33 per ton** of steam during the **low demand period.** Added to this would be the initial capital outlay for a new boiler and internal infrastructure cost. You would therefore require a 3.5-ton Electrode Boiler estimated at R372 000.00.

While the average cost of steam supplied by **coal boiler** is approximately **R104.01 per ton** of steam because of coal being the cheaper energy source, one should be aware of the risk areas that could affect your production:

- Delivery problems with coal
- Labour problems

- The negative impact to the environment and production, also affecting neighbouring areas and considering the pollution legislation that has to be adhered to.
- Additional boiler house required.
- New adjustments to existing steam reticulation network.
- Extra storage space required for coal.
- Possible contamination of products caused by smokes emissions.
- Start up time of boiler is much longer – 1 hour, therefore this could lead to overtime should there be a power failure.

After reviewing all relevant factors and information supplied by Brian Jennsen, it would be recommended to purchase a dual fuel system (electrode & HFO boiler) in order to rectify the current problem. The additional benefits that you may expect by using electric boiler are as follows:

- Cleaner source of energy been utilised thus meeting Environmental Standards
- Ease of operation, thus requiring less attention.
- Excellent Boiler Efficiency thus offering a quick response to steam demands – 20 minutes to achieve full pressure and steam from cold start.
- No space constraints.
- Lower rejection rates with consistent quality of steam.
- No additional capital outlay required.
- No labour problems
- No disruption to production

I trust that the above information has met your present needs, should you have any queries please feel free to contact us at your earliest convenience.

Yours faithfully

Lenny Chetty
Industrelek Advisor – Northern Province

APPENDIX E

TECHNICAL SPECIFICATION

The THOMPSON ELECTROPAC : High Pressure Package Steam Boiler is an electrode boiler operating on voltages from 380-volt to 550-volt 3-Phase and evaporation rates from 30 kg/hr to 2500 kg/hr. The standard working pressure is 1000 kPa.

1. DESIGN AND MANUFACTURING STANDARDS

In addition to compliance with the standards stated below, the boiler complies fully with the occupational Health and Safety Act of the Republic of South Africa of 1993 as amended. Where recognised standards do not comply, design, materials and construction are fit for purpose and in accordance with in-house standards and good engineering practice. Quality procedures are third party audited to ISO9001.

Pressure Parts

Boiler pressure parts are designed and constructed in accordance with the latest amendment of BS1894-1992.

2. BOILER VALVES AND MOUNTINGS

Valves and mountings comply with BS759 and are fitted to the boiler standpipes with suitable steam joints complying with BS2815 or sealed screwed joints.

Valves and mountings are suitable for the rating, pressure and temperature requirements

Standard Valves and Mountings

1 - Main Steam stop valve.
1 - Safety valve
1 Set - Water level gauge with isolating and blow-down
1 - Blowdown valve
1 - Feed water isolating valve
1 - Feed water check valve
1 - Dump solenoid valve
1 - Needle type conductivity bleed valve
1 - Pressure gauge

Thermal Insulation

The boiler shell is insulated with 50 mm thick 80 kg/m³ density mineral wool, wrapped with canvas.

Boiler Cabinet

The boiler shell, electrical supply and controls are within a sheet metal cabinet with enamel powder coated finish.

3. ELECTRICAL SUPPLY AND CONTROLS

1. A main circuit breaker to suit the boiler rating and with a fault current rating of minimum 25 kA.
2. Pump circuit breaker, contactor and overload to suit the pump rating.
3. Computer controls to adjust current, pressure and conductivity.

Electrode Assembly

Cast Iron Electrodes supported from electrode studs with porcelain insulators to the top flange. The electrodes are surrounded by a neutral shield also supported to the top flange.

Boiler Feed Water Pump

One boiler feed water pump is provided as standard and is of single-stage type and sized to suit the boiler working pressure and rating. The pump is fitted to the boiler and connected to the boiler feed check valve with suitably sized mild steel piping.

The boiler feed water pump is of Calpeda or equivalent manufacture at our option.

4. OPTIONAL ITEMS

The following items are optional and can be included if required:

- Boiler feed water (hot well) tank
- Blow down tank
- Auto blow down system
- Earth leakage system
- No-volt dump system
- Computer memory module
- Computer communication module.

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