ENERGY MANAGEMENT IN THE JORDANIAN CEMENT INDUSTRY

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Part One

Abstract

Energy is essential to economic prosperity and quality of life. However it can have detrimental effects on the environment if not used properly. Moreover, if energy resources are scarce in a given country, then its use will impose economic and financial burdens on the national economy.

The cement industry is energy-intensive, which adds a micro dimension to the macro issues mentioned above. Reducing energy consumption without due consideration to production requirements is not an optimal situation. What is needed is to arrive at a situation whereby energy is used rationally. The concept of rational use of energy has two embedded principles. The first is increased energy-use efficiency and the second is environmental protection.

Jordan Cement Factories (JCF), located in a developing country where energy resources are not indigenously available and, therefore, costly energy requirements are imported, have realised the importance of addressing the energy management and conservation issues. This thesis describes the efforts initiated and conducted by the author, to address the research problem of improving energy usage through the application of effective management techniques aimed at reducing energy consumption per unit of cement produced.

This present research has been concerned with energy management and efficient use of energy. The Jordan Cement Factories were used as a vehicle to demonstrate the proposed research methodology that aimed at improving energy consumption

and thus operational efficiency. The methodology is based on establishing statistically significant relationships between interacting problem factors, and assessing the economic impact of improving these factors. Economic evaluation entailed the development of economic models and an application methodology combined with illustrative case studies. Consequently, the problem of energy management has been presented in a wider perspective that addressed the whole management system at the organisation.

Towards that end, it was first necessary to show the significance of energy cost with respect to the overall manufacturing costs. The analysis of production costs, which demonstrated the significance of energy costs, was followed by the investigation and examination of the basic management factors that have direct impact on energy consumption at the JCF. Among these factors are, for instance, production line availability, production rate, average number of stoppages, and average duration of stoppages. These factors were determined using preliminary data analysis and the experience and technical knowledge of the researcher.

The statistical analysis proved the existence of strong relationships between energy consumption and management factors. Several models were developed for a set of selected production lines in the JFC at Fuhais and Rashadiya plants. These statistical models were generated using actual data for electrical energy and fuel consumption. The derived models have demonstrated the existence of strong relationships between energy consumption and management control factors; for instance, the values of R^2 *range from 60% to 90%. This implies that an equivalent* *percentage of the variations in energy consumption can be attributed to the selected management factors.*

The economic model developed in this research is concerned with demonstrating that effective management practices associated with proper maintenance and housekeeping can result in highly significant savings in energy usage. Although a simplistic methodology was used to evaluate the economic impact of any improvement programme, the economic treatment showed that the cost of improvement is actually negligible compared to the realisable savings in energy usage.

The research has dealt with the details of developing a coherent energy management model whose objective is to establish transformational management processes of certain high-level management factors into daily operations and controls. The high-level management factors are the same factors used as independent variables in the statistical and economic models, which statistically proved to be the major factors affecting the energy consumption at JCF.

The research has also presented a detailed analysis of the organisational and procedural aspects of energy management with concentration on management functions, especially planning, controlling, executing, organising, and auditing. A detailed mapping and analysis of these functions as the main components of an Energy Management System (EMS) resulted in establishing job descriptions, organisational charts, work instructions and procedures for all-important functions of the EMS.

The type of work described in this thesis could be extrapolated for application in other industries, particularly energy-intensive ones, to arrive at the objective of rational use of energy at the national and international levels. Comprehensive studies would need to be carried out for each type of industry prior to implementation.

The cost benefit analysis presented in this research proved, beyond any doubt, the importance of implementing the EMS in JCF. As a result of this implementation it is demonstrated that huge annual savings were realised.

Finally, as a result of improving energy control factors, introducing energy conservation measures and employing management techniques at JCF to guarantee the effectiveness of all such activities, resulted in an annual savings amount to about USS 3.5 million. Therefore, if the same or similar actions are undertaken by all cement, or other highly energy intensive industries then the savings could reach billions of dollars.

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Chapter One

Introduction

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Chapter One

Introduction

This chapter defines the problem of energy management and conservation in the cement industry; presents the research objectives, draws attention to the importance of energy and the need for energy conservation in Jordan as a whole, and defines the needs of the cement industry in particular. Finally it presents the organisation of the thesis.

1.1 The Importance of Energy

According to (Sadiq 1996) it is considered axiomatic that energy is a key factor in the policy planning and development of national economies since it interacts with a wide spectrum of economic and fiscal issues such as balance of payments, inflation, employment, investment and trade. He offers an alliteration, which follows from the concept that energy interacts with other factors of development policies such as: economy, environment, employment, enterprise, education, efficiency, export and equity; which he refers to as energy and eight E's.

Energy is a vital commodity in our lives, according to Elliott (1997) energy resources is a clear example of limited world resources whose use can have major impacts on the natural environment. Energy use is now considered central to most human activities and many of our environmental problems could be described in terms of our energy getting and our energy using technologies.

Light bulbs in our homes and kilns in the cement industry both require energy to function, but they use energy in different ways. Energy use also depends on many other factors, which include (i) economics: the current and future costs of energy and the ease of replacement of materials and devices with similar ones which use less energy; (ii) location: as areas enjoying lower energy prices tend to consume more energy; (iii) behaviour: which reflects the aspects of our life style; (iv) income levels: rich nations tend to consume more energy than poor nations; and finally (v) technology: more advanced technologies tend to be more energy efficient, therefore, consume less energy per unit of output.

It is not the intention of this research to analyse the above - mentioned factors in detail; they are mentioned here only to indicate the complexity surrounding energy as a commodity.

The following paragraphs illustrate the importance of energy to the economy and to industry. Moreover, an explanation is presented with regard to the importance of rational use of energy.

1.1.1 The Importance of Energy to the Economy

The world energy perspective has changed during the past twenty years or so, particularly after the oil price shocks of 1973 and 1979. This affected energy consumption patterns all over the world, and changed the focus of energy policies in different countries, in particular, industrialised countries. Table (1.1) shows the development of crude oil prices during the period (1970-1994).

Table (1.1)

Crude Oil Prices in Nominal and Real Terms

US Dollars per Barrel (1973=100)

Year	Nominal Oil Prices	Real Oil Prices
1970	1.67	2.36
1973	3.07	3.07
1974	10.77	9.87
1979	17.28	9.48
1980	28.67	13.93
1981	32.50	16.42
1986	13.53	6.02
1989	17.31	6.29
1990	22.26	7.05
1991	18.62	5.71
1994	15.53	4.68

Source: OPEC. Annual Statistical Bulletin, 1994.

Primary energy demand witnessed growth of all main five fuels (crude oil, coal, natural gas, nuclear energy and hydroelectricity), but at different rates, which were basically influenced by economic growth, energy prices, energy security (political considerations) and technological development. This facilitated development of nuclear energy technologies, enhanced the process of crude oil and natural gas exploration activities and substituted non-commercial with commercial energy. Moreover, growth of energy demand was influenced by efficiency and conservation efforts, and by structural changes in the economy (switching to less energy-intensive industries).

The growth of energy demand prior to 1974 had been accompanied by an almost identical global growth in economy (Khatib and Munasinghe, 1992). However, the oil price shocks mentioned earlier resulted in the decoupling of energy demand growth and economic growth, particularly in high-income countries, which were able to reduce wasteful energy consumption or improve the efficiency of energy use by adopting energy efficient technologies (World Bank, 1995). This is clearly illustrated in Table (1.2).

Table (1.2)

Annual Energy Demand and Economic Growth

	Economic Growth (GDP)(%)			**Energy Growth (%)**		
	Low Income* economies	Middle Income economies	High Income economies	Low Income* economies	Middle Income economies	High Income economies
1970-1980**	4.3	5.9	3.2	6.6	4.1	1.7
1980-1993	5.7	2.7	2.9	4.9	2.1	1.8

Source: World Bank, 1995

1.1.2 The Importance of Energy to Industry

According to the World Energy Council (1995), the industrial sector is the largest primary energy consumer, accounting for about 43% of total world consumption in 1992. The growth rate of industrial primary energy consumption amounted to around 1.9% per annum during the period (1971-1992). On the other hand, the value added of the industrial sector accounted for 40% of the value added produced in the world. Moreover, in OECD countries, energy intensity (a measure of the efficiency of energy use which relates energy consumption and output - see chapter 3) has declined by 1-2% per annum during the past two decades, largely due to the improvement in process technologies and increased use of recycled materials as inputs. For example, the use of the dry process for cement manufacturing (as opposed to the wet process) contributed to the decrease in energy intensity.

Table (1.3) shows the primary energy consumption and energy intensity ranges in 1990 for selected industries, including cement.

Table (1.3)

World Primary Energy Consumption and Intensities

for the Five Most Energy-Intensive Industries (1990)

Industry	Primary Energy Consumption(EJ)*	Energy Intensity (GJ** /tonne)
- Cement	6.2	4 – 6
- Iron and Steal	18.6	20 – 30
- Chemicals	18.5	-
- Petroleum Refining	12	3 – 6
- Pulp and Paper	5.7	22 – 30

Source: World Energy Council, 1995.

- EJ=10^{18} Joule
- **GJ=10^{9}Joule

The cement industry is highly energy intensive. Cement is produced by burning limestone to make clinker. The latter is blended with additives and then finely ground to produce different types of cement.

The following figure (1.1) shows the steps involved in cement production.

Figure (1.1)

Cement Production Steps

Step (I): Consumes less than 5% of total energy consumption

Raw Material Preparation

- Primary and Secondary Crushing of quarried material
- Drying the material (in dry process)
- Further grinding through either wet or dry processes
- Blending the materials

⇓

Step (II): Consumes about 80% of total energy consumption Clinker Production (wet or dry)

- Burning a mixture of materials:
  a) Limestone
  b) Silicon oxides
  c) Aluminium and Iron oxides.

⇓

Step (III): Finish Grinding

Cooled clinker is blended by simultaneous grinding and mixing with additives (e.g. gypsum and pozzolana) to produce cement.

Source: World Energy Council, 1995

1.1.3 The Importance of Rational Use of Energy to the Economy and to the Environment

As mentioned before, global awareness of the importance of promoting energy conservation and efficient use of energy use has been triggered by the oil price shocks, which occurred in the seventies and early eighties. Therefore, the main driving force for adopting energy conservation policies and measures was purely economic. However, now there is a growing awareness of the major problems involved in providing adequate energy supplies to meet the requirements of socio-economic development. These include local, regional and international (global) environmental pollution associated with energy consumption. This pollution includes global warming which is considered a major challenge and a serious threat to the international community. Consequently, it is now widely believed that a more rational use of energy resources will help reduce growth of energy consumption (or will improve the efficiency of energy use per unit of production) and therefore, reduce the related environmental problems. The rational utilisation of energy can be achieved through the application of new technologies, processes, policies, and appropriate energy conservation mechanisms that promote increased energy efficiency.

It can be further argued that conserving energy will actually make a new energy source available, since energy conservation will result in saving energy, whether in absolute terms or by decreasing the energy needed to produce one unit of production. This extra energy can be used to feed other units of production (so that more units can be produced), or to feed other production or service activities.

In 1997 the international community succeeded in formulating the "Kyoto Protocol". The Kyoto Protocol defines allowable greenhouse gas emissions for each industrialised country in terms of assigned amounts for the commitment period 2008-2012. The commitments add up to a reduction of 5.2% below 1990 levels, besides other specified commitment for other countries. (Grubb et al 1999). Although this does not apply to all countries, the protocol encourages developing countries to take similar measures. Moreover, opportunities for trading emissions permits will arise. Therefore, this will create more incentives for governments and firms to reduce energy consumption. The industrial sector will be called on to make a major contribution to meeting these targets.

1.2 Definition of the Problem

1.2.1 Need for Energy Conservation in Jordan

Sufficient energy supplies are necessary for maintaining production and enabling a modern society to function. Such goals as meeting the standards of living for a growing population, upholding national security, improving the quality of life, can only be achieved with increasingly large amounts of energy (Fritz, 1982). As Arisumundandar (cited in Fritz, 1988) pointed out, "the demand for energy arises out of a need for energy. The need for energy of a group of people, of groups of people, of a nation, is born out of a desire to live in a just and prosperous society. The demand for energy thus reflects, directly and indirectly, the political aspirations of the people".

Scott and Hafele (1989) point out that vast technology of exploration, extraction, concentration, transport, storage, conversion and distribution, together constitute a complicated delta of energy flows, which is interwoven with our social and economic network and is not without hazard. "Intensive direct effects and low- intensity long-term effects can threaten our health and our natural environment. The environmental impact from energy transactions is closely related to the material involved in these transactions".

As Dirken (1978) argues, energy has become the indispensable food of society and culture. It determines our daily life to a high degree, not only structuring labour, services, industry, communication and transport, but also social power. Because ownership of energy resources and technological knowledge gives the key to dominance, he argues that it should therefore, remain or be subjected to democratic control.

With this introduction, one can realise the importance of energy as a valuable resource as well as a critical factor for both economic productivity and better quality of life. Of interest to us, in this research, is how one can reduce any wasteful consumption of energy in an energy-intensive industry in a developing country that imports almost all of its energy requirements from abroad. The highly energy intensive cement industry has been selected as the focus of this work, and so illustrate the potential scope for management in other energy intensive industries.

Jordan is not endowed with sufficient energy resources to satisfy its total energy requirements. Therefore, it imports almost all the energy needed to carry out its socio-economic development activities. This, of course, constitutes a burden on the economy because of the high-energy bill. Consequently, energy conservation is given a high priority in the Jordanian energy policy.

Primary energy consumption in Jordan grew at high rates during the period (1974-1995). This was mainly due to the growth in national economy. However, more efficient use of energy could have been achieved without negatively affecting economic growth. One of the main indicators used for measuring the efficient use of energy consumption is Energy Intensity (EI), defined as the ratio of the quantity of energy used to the Gross Domestic Product (GDP), or as the quantity of energy required to produce one thousand units of GDP. As illustrated in Chapter Three, the development of energy intensity in Jordan does not show any clear trend or improvement in the efficiency of energy use. Therefore, the effect of the measures to encourage the rational use of energy adopted by the Government and other concerned industrial companies could not be easily isolated. This indicates the real need for a different type of analysis, perhaps at the level of the firm, in order to determine the real effect of energy, management and conservation policies and measures on the economy in general, and on specific industries in particular. *"Therefore, this research undertakes a comprehensive analysis of energy usage patterns and their associated costs, with the aim of determining how to improve the efficiency of energy use in the cement industry in Jordan. The results of this research will be very useful and applicable to other industries in the country as well as in other parts of the world."*

1.2.2 Energy and the Cement Industry

Cement manufacturing is highly an energy intensive process, and any reduction in specific energy consumption (energy needed to produce one unit of output), whether thermal or electric, will result in a direct cost saving to the company concerned. Therefore, cement industries have looked in the past for ways of achieving reductions in the amount of energy required to produce one unit of cement, and it is believed that they will continue to do so. In the case of Jordan, the energy bill of the cement industry is about 35 million US dollars per year, which represents around 70% of the total variable cost of cement manufacturing. Therefore, specific energy utilisation (energy unit/ton of cement) can be improved by eliminating operation inefficiencies through establishing a proper and effective energy management system.

The cement industry in Jordan has adopted several energy conservation measures, and has invested in more energy efficient equipment and devices. However, it is believed that there is still room for further improvements in the efficiency of energy use in cement production in the country. These improvements can be realised through the application of modern management tools that will increase plant availability, utilisation factors and thus decrease the number of stoppages and their duration. "*Therefore, the present research is addressing the problem of improving energy usage through the application of effective management techniques aimed at reducing energy consumption per unit cement produced.*"

1.3 Research Objectives

Based on the scope of the problem defined above, the research has the following set of objectives:

A - To assess the current energy consumption patterns in the industrial sector in Jordan, with special reference to the cement industry. Within the cement industry to identify opportunities to rationalise the use of energy, to assess the activities, and the barriers opposing, the exploitation of those opportunities.

B - To identify specific areas of improvement, savings and conserving of energy consumption in the cement industry that requires the analysis of cement manufacturing processes, costing and historical data which support the input-output behaviour of the cement factory as a whole.

C - To investigate the causes of high-energy consumption in Jordan Cement Factories (JCF) and demonstrate the potential and importance of energy saving through important lessons learned through implementing practical case studies.

D - To investigate the possibility of establishing statistical and economic models that relate energy consumption with management practices and factors, and their related economic impact on energy and production costs.

E - To develop at the Jordan Cement Factories (JCF) an Energy Management System (EMS) based on modern management techniques, which integrate with an overall total quality management philosophy.

1.4 Organisation of the Thesis

This thesis consists of nine chapters: Chapter One, **Introduction**, highlights the importance of energy to the economy and to industry, emphasises the importance of rational utilisation of energy to the economy, defines the problem of research, and presents the research objectives and organisation of the thesis.

Chapter Two, **General Background Information**, is a brief description of the Jordanian economy and the development of primary energy and electricity consumption (both total and sectoral). The relationship between energy and economy is analysed, with particular emphasis on the relationship between energy costs on one hand and the values of Gross Domestic Product, total exports and total imports, on the other.

Chapter Three describes the issue of **Rational Use of Energy** in terms of its definition, and its value and importance to industry and the economy as a whole. This chapter also includes energy terminologies, energy forms and conversion of energy from one form to another. It further reviews previous research and literature relevant to the subject of the thesis.

Chapter Four presents the **Methodology of the Research.** A description of the research approach adopted is presented in this chapter. The methodology of research reflects the author's way of thinking and presentation in attempting to solve the research problem.

Chapter Five deals with **Energy Costing** (economics), particularly costs related to fuels and electricity used for cement production. The chapter attempts to analyse the cost elements of the cement industry; with the objective to highlight the large weight of the cost of energy relative to other cost items. This justifies the need and the importance for conducting the research directed towards improving energy management and conservation.

A discussion of the **Practical Energy Management Experience of cement industry in Jordan** is presented in Chapter Six, which contains an analysis of reasons and causes of the increase in energy consumption and a presentation of case studies which prove the importance and potential for energy saving.

Statistical and Economic Modelling and Analysis built by the researcher is illustrated in Chapter Seven. The statistical model reflects the impact of emergency stoppages, production rate and availability on electricity and fuel consumption pertaining to cement industry in Jordan. The economic model, on the other hand, carries the analysis a step further. It attempts to formulate an economic model based on the results of the statistical model. It further checks for the significance of savings as a result of adopting energy management measures.

Chapter Eight describes the aspects of **Energy Management in the Cement Industry in Jordan.** This chapter presents an additional and original contribution of the author in terms of the institutionalisation at the Jordan Cement Factories of an Energy Management System (EMS), which employs the principles of management science in achieving energy conservation objectives.

Finally, Chapter Nine presents an overall **Discussion** of the research work and highlights important **Conclusions** therefrom.

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Chapter Two

General Background Information:

Economy, Industry and Energy in Jordan

Contents

2.1 Introduction

2.2 The Geography of Jordan

2.3 The Jordanian Economy

2.4 The Jordanian Energy Scene

2.4.1 Domestic Energy Resources Development.

2.4.2 Energy Demand and Energy Prices.

2.5 Conclusions

Chapter Two

General Background Information:

Economy, Industry and Energy in Jordan

2.1 Introduction

This chapter sets the present study in its geographic and economic context beginning with a brief outline of Jordan's geographical position and characteristics. It then goes on to indicate the salient features of the Jordanian economy, before highlighting the development of domestic energy resources. Particular emphasis is placed on the relationship between energy and economy, specifically between energy costs and the values of certain economic indicators such as GDP, total exports and total imports.

2.2 The Geography of Jordan

Jordan, which is known also as the Hashemite Kingdom of Jordan, is a small Arab Country in the Middle East. The Arab Middle East, with Jordan at its centre, has acquired a special position of importance. Throughout its long history, it has attracted the attention of many empires and has always been subject to political, economic and social pressures and influences from different directions. The area has witnessed the rise of many civilisations and is the cradle of the three great monotheistic religions.

Jordan is situated near the south eastern shores of the Mediterranean, between longitudes 34 and 39 east, and latitudes 29 and 33 north. It is boarded by Syria from the north, Iraq from the east, Saudi Arabia from the south, and by occupied Palestine from the west. The total area of Jordan is around 90,000 sq km. The climatic and soil conditions, with the exception of the low-lying land of the Jordan Valley, are not generally favourable for intensive agriculture, only about 8 percent of the area is normally cultivated (Ministry of Information, 1978). The remaining parts are desert or barren hills.

The country can be divided into three main regions distinguished by topography and climate: the highlands, the Jordan rift valley, and the desert. The highlands, which adjoin the valley, extend from the Syrian border on the north, to the Gulf of Aqaba in the south. The average annual rainfall is 380 mm. To the west is the Jordan rift valley, which reaches a maximum of 14 miles in width and 1300 feet below sea level at the Dead Sea (lowest spot on earth). West of the valley, the level rises again to the Palestinian hills. The desert region to the east and south west occupies nearly 87 per cent of the total area. For centuries, only Bedouins have lived there. The Government has succeeded recently in its efforts to settle some of them by building schools and clinics, and providing them with water, electricity and other infrastructure requirements (Ministry of Information, 1978).

The country has generally a Mediterranean type of climate, though its temperatures vary from one region to another in certain seasons. In the eastern and southern parts, the weather is warmer than the western parts. Temperatures reach 33C in summer, but rarely below zero in winter. The rain season usually starts in November and ends in April. Rainfall amounts vary from one year to another, which affects agricultural production on a large scale. In the highlands, the annual rainfall sometimes reaches 600 mm, while in the desert it rarely reaches 100 mm. The Jordan Valley has long, dry and hot summers with temperatures rising to more than 40C, while the highlands have a more moderate climate (Ibid).

2.3 The Jordanian Economy

The Jordanian economy enjoyed high growth during the period 1973-1984, boosted by foreign assistance and loans, worker's remittances and export to regional markets. This trend changed in the mid-eighties as a result of the rapid decline in the oil prices and the subsequent slowdown in the regional economy.

The economic crisis of 1988-1989, which occurred as a result of an increase in debt burden and debt servicing requirements, led to a drastic slowdown in growth and a severe deficit in fiscal and external accounts. This impelled the Jordanian Government in 1989 to undertake policy adjustments to stabilise the economy and to restore growth. Also these policy adjustments called for the enhancement of the role of the private sector and adopting aggressive privatisation programs and avoiding the subsidy practices so that the goods and services would reflect its real market value. Subsequently, due to regional and international developments, including the Gulf crisis, the GATT agreement and other developments the Jordanian Government has modified the restructuring program in order to cope with these new developments. Consequently positive signs of the economic recovery have occurred (Ministry of Planning, 1993). However, major structural growth constraints still remain, as will be illustrated in the following sections.

(As) can be calculated from table (2.1) Gross Domestic Product (GDP) in 1989 declined by around 13%.

Table (2.1)

Gross Domestic Product (million JD) at Constant Prices

(1985 = 100 %)

Sector	1988	1989	1990	1991	1992	1993	1994
1.Industry (a)	234.8	281.8	287.6	274.8	307.2	309.3	334.1
2.Agriculture	164.7	124.4	163.1	178.7	209.6	154.3	155.8
3.Electricity &Water	63.1	69.4	53.3	56.2	58.7	67.1	71.4
4.Construction	108.3	86.1	80.7	89.2	138.6	174.1	181.2
5.Transport, Storage & Communication	288.8	279.9	270.2	255.1	278.5	289.9	321.7
6. Services (b)	1064.8	883	835.8	887.5	946	1060.3	1105.3
7.Total(1+2+3+4+5+6)	1924.5	1724.6	1690.7	1741.5	1938.6	2055	2169.5
8. GDP at Factor cost (c)	1876.8	1680.5	1662.2	1705	1911.6	2013.4	2127.9
9. GDP at producers prices(d)	2183.2	1889.6	1908	1942.8	2255.1	2387.2	2527.1

Source: *Monthly Statistical Bulletin, Central Bank of Jordan, November 1995.*
(a) *Mining and Quarrying and Manufacturing.*
(b) *Wholesale and Retail Trade, Trade, Restaurants and Hotels + Finance, Insurance, Real Estate and Business services + Community, Social and personal services + Producers of Government Services + Producers of private Non-profit services to Households + Domestic services of Households.*
(c) *Total (1+2+3+4+5+6) – Imputed Bank Service charge.*
(d) *8 + Indirect Taxes – Subsidies.*

In 1990 and 1991 the GDP growth rates were marginal and amounted to around 1%. In the year 1992 the growth rate of GDP jumped to around 16% due to domestic investments in housing and other construction activities carried out by workers returning from the Gulf countries, particularly from Kuwait. In 1993 and 1994, the GDP growth rates were 1.9% and 2.1% respectively.

The GDP share of the industrial sector (Manufacturing and Mining and Quarrying) increased by 6% during the period 1988-1994. The GDP share of the agricultural sector slightly decreased by around 1% (in 1985 prices) during the same period. Moreover the GDP share of the electricity and water increased by 2% (in 1985 prices) during the same period. The GDP share for both the construction and transport, storage and communications sectors grew by 9% and 1.8% respectively (in 1985 prices) during the same period. Finally, as for the services sector, which accounts for almost two thirds of the Jordanian economy, its GDP share grew by 0.6% during 1989-1994.

2.4 The Jordanian Energy Scene

Jordan lacks domestic energy resources, which can be commercially utilised through traditional technologies with the exception of a small amount of natural gas currently being utilised for electricity generation). Currently, Jordan imports almost all the energy required for its socio-economic development. The cost of imported energy constitutes a significant burden to the national economy. In 1995, it reached around 7% of the GDP, 12.7% of total imports, and 31% of total exports (Ministry of Energy and Mineral Resources, 1996 annual report).

The burden of energy cost on the Jordanian economy, has underlined Jordan's need to expand domestic energy production and construction and/or use energy more effectively.

2.4.1 Domestic Energy Resources Development

With the increase of oil prices since the seventies, Jordan has vigorously pursued a policy of exploring and exploiting oil, gas, oil shale and renewable domestic energy resources (solar and wind) in order to decrease its reliance on imported oil. Despite declining oil prices and the decrease in international exploration activities, Jordan has been successful in attracting a number of international oil exploration companies. In parallel, the Government agency, the Natural Resources Authority (NRA), has also continued to carry on exploration activities. Jordan has succeeded in making two small oil discoveries in Al-Azraq (eastern part of Jordan) and Sirhan (northern part of Jordan) basins, and the first gas discovery in Risha, in 1987. The Jordanian Government has also initiated number of studies to develop its oil shale resources and executed several pilot and commercial projects to develop its solar and wind energy resources.

The country's domestic energy resource development strategy addresses four key issues: (i) the exploration and exploitation of oil and gas: (ii) planning for natural gas development; (iii) natural gas pricing; and (iv) the technical and economic feasibility of oil shale development (Natural Resources Authority, 1990).

(A) Oil and Gas Exploration

Jordan covers an area of approximately 90,000 km^2, with 78% of its land covered by possible oil-bearing rocks. Between 1946 and 1978 exploration activities, geological and geographical surveys and drilling of 14 exploratory wells were carried out by several foreign oil companies. Although oil and gas were observed in several wells, no commercial oil and gas discoveries were made. The companies expecting to find large and middle-sized oil fields were disappointed and abandoned their concessions.

While concerned about the loss of interest shown by the oil companies, the Government remained convinced that past exploration efforts were inadequate. Consequently, it decided to use its own technical and financial resources to explore for oil and gas. The Natural Resources Authority (NRA) has been in charge of all exploration since 1981. It first undertook a revision and reassessment of all past geological, geophysical and well data. This was followed by additional seismic surveys, the drilling of 49 wells, and a re-evaluation of Jordan's hydrocarbon resources. On the basis of its exploration efforts, NRA carried out extensive geophysical and geological evaluations of Jordan's petroleum acreage.

In view of the increasing burden imposed by oil imports, the Government of Jordan's (GOJ) strategy for oil and gas exploration emphasises accelerating the exploration and the development of domestic hydrocarbon resources. The strategy consists of: (a) promoting private investment through an open-door policy to attract international companies. The open-door policy resulted in contacts with more than 40 oil companies and the signing of production-sharing agreements with three international oil companies (AMOCO, Hunt and Petrofina). The NRA has also signed an assistance agreement with the Austrian OMV to explore the southern Sirhan area. In addition, NRA has signed technical cooperation agreements with PetroCanada International Assistance Cooperation (PCIAC), which began to promote the Risha areas in 1989. A similar agreement with Japan National Oil Company has been signed for the promotion of the northern Sirhan area; (b) developing oil reserves in the Azraq area; (c) evaluating the gas discovery in the Risha area by defining the limits of the reservoir and estimating reserves; (d) preparing gas development and utilisation plans on the basis of proven reserves and sustainable gas production profile from Risha Reservoir; (e) strengthening NRA/MEMR* technical expertise by providing training abroad in state-of-the-art exploration, production, gas utilisation techniques; and establishing facilities within NRA for advanced geological, geophysical, geochemical, reservoir and gas engineering staff (Natural Resources Authority, 1990).

GOJ's strategy for oil and gas exploration is sound. NRA undertook a reassessment of Jordan's hydrocarbon resources at a time when International Oil Companies (IOC's) showed little interest in exploring in Jordan. Between 1975 and 1988, NRA spent about 220 million US dollars in oil and gas exploration activities. NRA efforts have established that Jordan's petroleum geology is favourable to the generation of hydrocarbons. The first oil and gas discoveries, although small, have generated IOC's interest.

NRA's experience has also shown that oil traps found in the Azraq basin are small and difficult to locate. Similarly, the Risha reservoir is known to contain complex stratigraphic traps, making it difficult to determine the size of gas reserves and the rate of sustainable production. The complexity of structures, as well as reservoir conditions, require the use of state-of-the art techniques in future exploration and development activities. NRA has recognised these difficulties and has taken a number of steps to overcome them, including the improvement of data quality by undertaking extensive seismic surveys using vibroseis techniques and reprocessing and reinterpreting the data from the Risha region with cooperation of PetroCanada. NRA has also set up working groups to integrate and evaluate all data from Risha and Sirhan in order to reach a better understanding of the geological complexities of these areas.

(B) Natural Gas Development and Utilisation

The first use of natural gas in Jordan's energy sector started in March 1989 with the use of Risha gas for electric power generation. Natural gas development and utilisation in

Jordan is influenced by three main factors: (a) unknown nature of natural gas reserves; (b) potential demand for natural gas as a substitute for oil in power generation and other uses; and (c) pricing of natural gas (Al-Sheyyab, B 1993).

Planning for natural gas development is entirely dependent on the size of recoverable gas reserves. At present, there is a great deal of uncertainty about the size of possible gas reserves in Jordan. The extent of the reserves in the already discovered Risha gas field has not yet been defined. In the medium term, planning for gas development and utilisation is dependent on the size of the Risha gas discovery. Risha wells 3,6,8 and 16 are found to be productive. However, the extent of the size of the natural gas resource is unknown.

Although, vital information about the size of natural gas reserves is still lacking, this in no way diminishes GOJ's need to formulate a strategy for gas utilisation. GOJ's main strategy is to substitute gas for fuel oil in power generation. Based on the present consumption pattern, natural gas can be substituted for fuel oil in electric power generation in the cement, phosphate, potash and fertiliser industries. Preliminary studies conducted by MEMR estimated potential gas demand, both in the power plants and industries, to be about 350 million cubic feet per day (9.9 giga litres per day, Gld). This is based on the assumption that the conversion of all steam and gas turbine power plants and industrial facilities would represent a maximum possible peak natural gas demand of 350 mcfd. (9.9Gld). This demand exceeds even the envisioned maximum reserve; a trillion cubic feet, (28 trillion litres) and the production scenario for Risha gas of 200 mcfd (5.66 Gld) (Al-Sheyyab, 1993).

On the basis of the available information, GOJ has made a preliminary assessment of the Risha gas reserves at 58 billion cubic feet (1600 billion litres), with a refill of 20 mcfd (0.57 Gld) of production for at least three to four years. It has completed the construction of 334 km of 132 kV transmission line from Amman to the Risha gas field and installed and commissioned 3 x 33 MW gas turbines (Jordan Electricity Authority, 1990) GOJ's attempted to utilise natural gas in power generation instead of flaring it during the long-term testing period, is a sound policy.

However, this decision entails certain risks, namely, drops in pressure and difficulty in sustaining gas production. If the long-term test results confirm the commerciality and sustainability of the reserves, then the plan is to increase the number of gas turbines until the transmission capacity (180 MW) is achieved.

(C) Oil Shale

Jordan potentially has very large oil shale reserves of over 40 billion tonnes. The major commercial-scale deposits known so far are estimated at about 1.1 billion tonnes at El-Lajun, 1.2 billion tonnes at Al-Sultani, and 8 billion tonnes at Jurfed-Darawish (Ministry of Energy and Mineral Resources, 1989). The average oil content of Jordanian oil shale is 10% by weight, which is good quality shale, comparable to the high quality shale found in the US and elsewhere. All these deposits are located south of Amman in central Jordan and are easily accessible from the desert highway between Amman and Aqaba. NRA conducted a detailed survey, drilled core holes and performed laboratory work to determine proven geological reserves, their quality, oil content and calorific value of the El-Lajun and Sultani deposits. Based on the favourable results from oil shale analyses of these deposits, the Natural Resources Authority commissioned a study by Kloeckner / Lurgi. Jordan Electricity Authority (JEA) commissioned three studies by Brown Boveri Company (BBC) of Switzerland (now

ABB), Lummus Cómbustion Engineering of Canada and Bechtel / PyroPower of USA to investigate the techno-economic feasibility of exploiting oil shale deposits. Kloeckner/Lurgi investigated the feasibility of using El-Lajun oil deposits for constructing an oil shale retorting project to produce 5000 b/d of syncrude and generate 350 MW power from the spent shale by fluidised bed combustion (FBC). Kloeckner/Lurgi completed its study in two phases and submitted its final report to NRA in April 1988. Lummus Combustion Engineering and Bechtel/PyroPower investigated the techno-economic feasibility of the direct combustion of Sultani oil shale, using FBC technology, to install a 25-MW demonstration pilot power plant (Ibid).

Bechtel-PyroPower has also investigated FBC technology for constructing 50 and 100 MW power plants. The report by Lummus was submitted to JEA in October 1988. The Bechtel/PyroPower report was submitted in February 1989. These prefeasibility studies concluded that the exploitation of oil shale is technically viable, both for the extraction of shale oil and as a fuel for direct combustion in power generation (Ibid).

(D) Renewable Energy

Solar, wind and biogas constitute the main renewable energy resources in Jordan, which is endowed with a high radiation intensity averaging 5 to 7 kWh/m^2. This is one of the highest solar energy intensities recorded anywhere in the world. It has a potential wind regime suitable for electricity generation and for mechanical water pumping. Biogas from animal and domestic wastes is estimated to substitute about 130,000 tons of oil equivalent (toe) per year (Ministry of Energy and Mineral Resources, 1989).

Current activities in renewable energy consist of a set of separate projects, which are being carried out mainly through bilateral assistance. These activities include: solar water heating, photo- voltaic applications, the use of wind energy for water pumping and the implementation of a pilot biogas system. Around 100,000 solar water heater units have been installed in approximately 26% of Jordan's households (Ministry of Energy and Mineral Resource, 1988). Currently, over 50 manufacturers are producing solar hot water systems in Jordan. The industry has a capital outlay of about 5 million US dollars, employs over 500 technicians, and has an annual production capacity of about one million square feet of collector area, equivalent to about 28,000 household units (Ibid). The Wind Farm in Jordan (4 wind turbines x 80 kW each) financed by a World Bank loan, established the technical feasibility of wind power generation (Ibid).

These ongoing activities have afforded access to excellent data, processing equipment, adequate laboratory facilities, and a pool of competent staff. In addition, research and development efforts undertaken by the Royal Scientific Society (RSS), in collaboration with bilateral and multilateral agencies and governments, have established Jordan as a regional centre for testing, developing and disseminating Renewable Energy System (RES) technologies. MEMR has formulated an action plan to establish the efficiency of various renewable energy technologies, which includes: (a) assessing climatic data; (b) establishing the efficiency of RES; (c) improving the cost effectiveness of RES; and (d) increasing the rate of dissemination of established and reliable systems. The action plan, when implemented through ongoing and potential activities in solar, wind and biogas exploitation, is projected to supply up to 3% of Jordan's energy needs by the year 2000 (Mustafa, 1993). MEMR should continue to evaluate ongoing activities, coordinate the fragmented responsibilities across different agencies and prioritise specific implementation tasks in the development of RES.

2.4.2 Energy Demand and Energy Prices

(A) Petroleum Products Demand

Demand for petroleum products grew on the average by around 14% per annum during the period 1975-1984, and declined to 2% per annum during the period 1984-1988. The growth rate of demand for petroleum products was around 5% during the period 1988-1995. The main reason for this growth was the Gulf crisis, during which more than 300,000 Jordanians came back from the Gulf countries, particularly from Kuwait. Table (2.2) summarises the main trends of petroleum products consumption during 1975-1995.

Table (2.2)

Petroleum Products Consumption

(1975-1995)

Year	LPG	Gasoline	Jet Fuel	Kerosene	Gas Oil	Fuel Oil	Total
1975	28	160	76	132	233	133	752
1982	75	311	310	178	684	578	2136
1984	92	342	256	150	695	890	2425
1985	97	342	237	139	748	930	2493
1988	123	352	199	166	804	1071	2715
1989	125	356	244	161	816	1062	2764
1990	122	360	234	159	848	1338	3061
1991	131	384	165	158	823	1227	2888
1992	172	435	219	297	857	1370	3350
1993	186	449	232	246	894	1437	3444
1994	208	469	235	241	975	1474	3600
1995	225	507	255	225	1048	1566	3826

Year (Periods)	1975 – 1984	1984 - 1988	1988 – 1995
Growth Rate (%)	14	2	5

Source: From 1975 - 1989 Jordan Petroleum Refinery Company (JPRC) (1990).

Figures are calculated in thousand tons of oil equivalent.

From 1990 - 1995 Ministry of Energy and Mineral Resources, Jordan.

(B) Electricity Demand

High growth rates in electricity consumption-14% per annum (p.a.) during the period 1975-1984 reflected high investment levels which generated large increases for electricity demand in various sectors. During 1975-1984 demand for electricity in the household sector grew at a very high rate of 15% p.a., reflecting the sector's heavy investment in energy-using household appliances; made possible by an increase in disposable income due to a high level of remittances from Jordanians working abroad.

The rate of growth of the household sector's demand for electricity declined to 8% p.a. during the periods 1984-1988 and 1988-1995, as a result of saturation as well as of a decline in remittances from Jordanians working abroad.

Industrial demand for electricity also grew at a very high rate, 12% p.a. during 1975-1984, reflecting the expansion and diversification of Jordan's industrial base and the setting up of energy-intensive industries such as cement and potash. In addition, the increased availability of cheap power encouraged the industrial sector to buy power from the grid. The rate of growth of industrial electricity demand declined to 5% p.a. during 1984-1988, reflecting the slow down of industrial activity and the absence of new energy-intensive industrial investment. However, industrial demand for electricity grew by about 7% during the period 1988-1995, due to an increase in industrial production.

A very significant addition to electricity demand in recent years has come from the water-pumping sector. Annual growth rates actually increased from 19% during 1975-1984 to 31% during 1984-1988. Water pumping accounted in 1995 for 19% of total national electricity demand, compared to 8% in 1975 (Jordan Electricity Authority, 1991-1994).

The growth of other users of electricity (which include commercial and street lighting) amounted to 13% during 1975-1984, compared with 8% during 1984-1988 and 1988-1995. Table (2.3) shows electricity demand by sector during the period 1975-1995 (Ibid).

Table (2.3)

Electricity Demand by Sector (1975-1995)(GWh)

Year	Industry	Household	Water pumping	Other	Total
1975	165	92	29	70	356
1982	488	455	98	233	1274
1984	851	604	151	338	1944
1985	903	655	215	398	2171
1988	1040	821	446	454	2761
1989	1128	844	472	514	2958
1990	1189	874	545	481	3089
1991	1181	928	548	484	3141
1992	1342	1074	688	572	3676
1993	1449	1192	702	638	3981
1994	1519	1317	768	726	4330
1995	1669	1411	916	789	4785

Growth Rates (%)

1975-1984	12	15	19	13	14
1984-1988	5	8	31	8	9
1988-1995	7	8	11	8	8

Source: Jordan Electricity Authority reports

(C) Energy Pricing

One of the main thrusts of the government's energy strategy is the economic pricing of petroleum products and electricity. Jordan's pricing strategies aim at removing energy subsidies by bringing domestic energy and electricity prices in line with their respective economic costs.

(C.1) Petroleum Product Pricing

Petroleum products prices were increased between 1978 and 1985 to reflect the increase in the world market prices, to eliminate subsidies, and to provide a source of revenue for the government budget. In 1988, petroleum revenues of 70 million Jordanian Dinars accounted for 21% of government total tax revenues and 13% of total revenue receipts.

Despite the decline in world oil prices, the Jordanian Government has continued to raise domestic petroleum product prices to try to maintain these prices in real terms and to eliminate any existing subsidies; promote efficiency in energy use; and finally, raise more revenue for the government in its effort to reduce the deficit. Following the May 1989 price increase, and even after reflecting the full impact of the depreciation of the Jordanian Dinar against the US Dollar, the average price for petroleum products became 28% above the border price which represented the petroleum products price in the neighbouring countries. Table (2.4) illustrates the development of Jordanian petroleum product prices during the period 1975-1995.

Table (2.4)

Petroleum Product Prices (1975 - 1995)

Year	Regular Gasoline Fils*/Liter	Super Gasoline Fils/Liter	LPG Fils/Liter	Kerosene Fils/Liter	Gas oil Fils/Liter	Fuel Oil JD/Ton
1975	75	95	1050	20	20	8
1981	160	190	1650	60	60	50
1983	165	195	1650	65	65	50
1984	180	210	1800	65	65	50
1985	180	210	1800	65	65	50
1986	180	210	1800	65	65	36.5
1988	180	210	1800	65	65	33.4
1989	220	270	2000	75	75	33.4(electricity) 50(Industry)
Domestic prices as a (%)of Average1989 world prices	251	281	192	99	98	86
1992	220	300	2000	75	105	41.4(electricity) 65(Industry)
1993	220	300	2000	90	105	49(electricity) 65(Industry)
1995	220	300	2000	90	105	49(electricity) 65 (Industry)

Sources: MEMR Annual Reports

* Fils = 10^{-3} JD

At present and in accordance of an agreement with Jordan refinery company, the government policy is to set the prices for all petroleum products at the retail level and to provide a fixed margin for refining, transportation and distribution activities. Under this framework, taxes on petroleum products are determined as a residual of gross revenue received from the sale of all petroleum products minus the total costs of crude oil purchases, refining transport, distribution and retail sales. The current pricing formula provides the refinery with cost-plus, guaranteed-fixed return between 7.5% and 16% on a paid -in-equity of JD 32 million. This system of refinery pricing eliminates the incentive for the refineries to pursue efficiency, including improvement in the efficiency of energy use.

(C.2) Electricity Tariffs

The present electricity tariff structure consists of:

(One) max demand (kW) rates and time-of-use energy (Kwh) rates for bulk supply to the distribution companies and large and medium industries;

(Two) an increasing block energy (kWh) rate for domestic consumers and public buildings;

(Three) flat energy (kWh) rates for commercial consumers; and

(Four) a declining block energy (kWh) rate for small industries

Also to minimize the reactive load in the electrical power system, which causes operational difficulties, there is an additional low power factor (<85%) penalty for distribution companies and large and medium-sized industries.

Over the years, JEA and MEMR have gradually adjusted the tariff to remove government subsidies or, in other words, to reflect the true economic cost of producing, transmitting and distributing electricity represented by the Long Run Marginal Cost (LRMC).

This trend can be clearly manifested by comparing the relationship of average tariff to economic cost of production in 1988 and 1996. In 1988 the ratio was 62% compared with about 107% in 1996. In other words the tariffs have moved from subsidy to profit. Table (2.5) shows the details of the calculation of average tariff/economic cost ratio for 1996.

The Government's subsidy is clearly apparent for street lighting and the agriculture sector while it is less apparent for water pumping and almost non-existent for domestic, small and medium sized industries. However, these subsidies are being compensated by other consumers; primarily large industries, bulk consumers, large commercial centres and hotels.

The electricity tariffs in Jordan are, thus, more or less free of major distortions except for certain cross subsidies. JEA and MEMR are planning to eliminate such minor distortions in due course. In comparison with other countries in the region or elsewhere in the third world, the electricity tariffs in Jordan are more balanced. This will make the privatisation of the electricity sector, a process that began with the conversion of JEA into a national company in September 1996, an easy task.

Table (2.5)

Comparison of Existing Electricity Tariffs with Economic Cost of Supply

Categories	Economic Costs (Fils/kWh)	Avg. Tariff (Fils/kWh)	Avg. Tariff As (%) of Economic Costs
Large Pumping	27.82	30.00	107.84
Bulk Industries	26.31	37.68	143.24
Domestic	44.23	42.33	95.70
Small Commercial	48.35	50.00	103.41
Small Industry	31.18	30.00	96.21
Small Pumping	36.05	30.00	83.21
Agriculture	38.78	21.00	54.15
Street Lighting	45.66	13.00*	28.4
T.V & Broadcasting	38.81	45.00	115.96
Large Commercial	41.72	50.00	119.85
Medium Industry	29.50	28.36	96.13
Hotels	43.79	50.00	114.19
Average	37.68	35.61	96.52

Source: JEA Planning Department, March 1996

* Applied to Consumption above 1988 Level.

2.5 Conclusion

This chapter has shown that during the 1970s and 1980s, Jordan experienced a period of high and rapid economic growth, followed by an economic crisis. However, since 1989, the government has taken steps to stabilise the economy.

Regarding energy, it was shown that due to its limited natural resources, Jordan relies heavily on imported energy. To reduce this dependency, efforts were increasingly being made to explore and exploit local resources. Such efforts are particularly important in view of the greatly increased demand for energy, especially electricity, caused by an increase in disposable incomes and industrial diversification.

Therefore, the chapter has highlighted the size of the burden, which is caused by energy on the national economy of Jordan. This is especially true as almost all energy needs are imported to Jordan. On the other hand, it helps in justifying all attempts to conserve energy and protect the environment.

Another important aspect of the government's energy policy has been to remove subsidies, bringing energy prices on parallel with the true economic cost of production, transmission and distribution. Thus, tariffs are more or less free of major distortions.

The characteristics of the Jordanian economy and energy situation described in this chapter underlined the importance of rational energy use (especially in the highly energy intensive industries, the cement industry's role is particularly important here because of its energy intensiveness and the proportion of energy that it consumes), not only to minimise costs to individual users, but also for the benefit of the economy as a whole. The following chapter accordingly addresses that issue.

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Chapter Three

Rational Use of Energy

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Chapter Three

Rational Use of Energy

3.1 Introduction

The importance of energy to the economy was highlighted in Chapter One, emphasising the importance of rational utilisation of energy, to industry and to the economy, while in Chapter Two the general background of the Jordanian economy and the development of primary energy and electricity consumption (both total and sectoral) was illustrated. The relationship between energy and economy in Jordan was analysed, with particular emphasis on the relationship between energy costs on one hand and the values of Gross Domestic Product, total exports and total imports, on the other.

This chapter addresses the issue of the rational use of energy in terms of definition, value, the importance to industry and importance to the economy as a whole. It also includes energy terminologies, energy forms and conversion of energy from one form to another. It further reviews previous research and literature relevant to the subject of the thesis.

According to the energy dictionary of the World Energy Council (1992) the definition of rational use of energy is as follows: "utilisation of energy by consumers in a manner best suited to the realisation of objectives, taking into account social, political, financial, environmental etc., constraints". Therefore, rational use of energy has to do with how consumers behave when they use energy. Moreover, this behaviour is driven by certain objectives; including conservation to reduce financial implications or to reduce environmental pollution etc.

The primary sources of world commercial energy today are mainly non-renewable, i.e. oil, natural gas, coal and conventional nuclear power. Renewable sources, which are mostly non-commercial, are less widely used, and include hydropower, geothermal, solar, ocean energy and fuel wood, on which 70% of the people in developing countries depend (Brundtland, 1988). Brundtland defines the term commercial energy as signifying those resources that are exploitable using proven and commercially available technologies. Although, in theory all the various energy sources can contribute to the world energy mix of the future, she points out that each has its own economic, health and environmental costs, benefits and risk factors that interact strongly with other national and global priorities. She suggests that energy choices in the 1950s and 1960s were relatively straight forward, being directly contingent on production costs. Now, however, these other aspects have become increasingly important. As Brundtland puts it, "in order to achieve sustainable development in the future, we must now be much more careful, looking more to the future when we make our choices" (Brundtland, 1988, p 102).

This implies that there are more reasons to use energy in a rational manner, since most energy sources are not renewable. Moreover, we cannot afford to continue in an irresponsible consumption behaviour when we know the economic and environmental implications of such a behaviour are of great importance.

It must be admitted that the oil market is influenced by geopolitical forces together with market forces. Therefore, it seems that, at times, production capacity far exceeds the consumption demand, while at other times the opposite is true. However, capacity level or availability is not the proper tool to use for a non-renewable resource where the environment and future needs must be taken into account. This could lead to a misinterpretation of future energy balances and an over exploitation of petroleum resources. Policies should be guided by the need to conserve energy for future generations and by concern for the environmental impact of burning fossil fuels (Brundtland, 1988).

3.2 Basic Definitions

3.2.1 Energy

Henry and his colleagues (1980) provide a clear and exact definition of energy as follows:

"Energy is the ability to produce an effect through the transfer of heat or work. Thermodynamics recognises that the transfer of energy to or from a system can be accomplished only by a work effect or a heat effect. Work transfer occurs if a force moves an object for a certain distance and heat transfer is the result of energy flow due to a temperature difference" (p 21).

3.2.2 Forms of Energy:

Energy has several forms according to the world Energy Council (1992), which include the following:

A) Chemical Energy:

Fuel, such as natural gas or oil, contains an amount of energy measured in its ability to release this energy in the form of heat through a chemical change; known as combustion. This energy form is described as **Chemical Energy.**

B) Kinetic Energy

Natural forces such as wind, possess energy in its motion (momentum) since it has the ability to exert force on and cause a displacement in a given mechanism such as a windmill. Causing this displacement constitutes doing work. Energy carried by motion as in the case of wind is called **Kinetic Energy.**

C) Potential Energy

Any object at a high elevation possesses potential energy. **Potential Energy** describes the amount of work that can be done by an entity through the change of its physical status from a high state to a lower state. The high state of a quantity of water lies in its location at a high elevation.

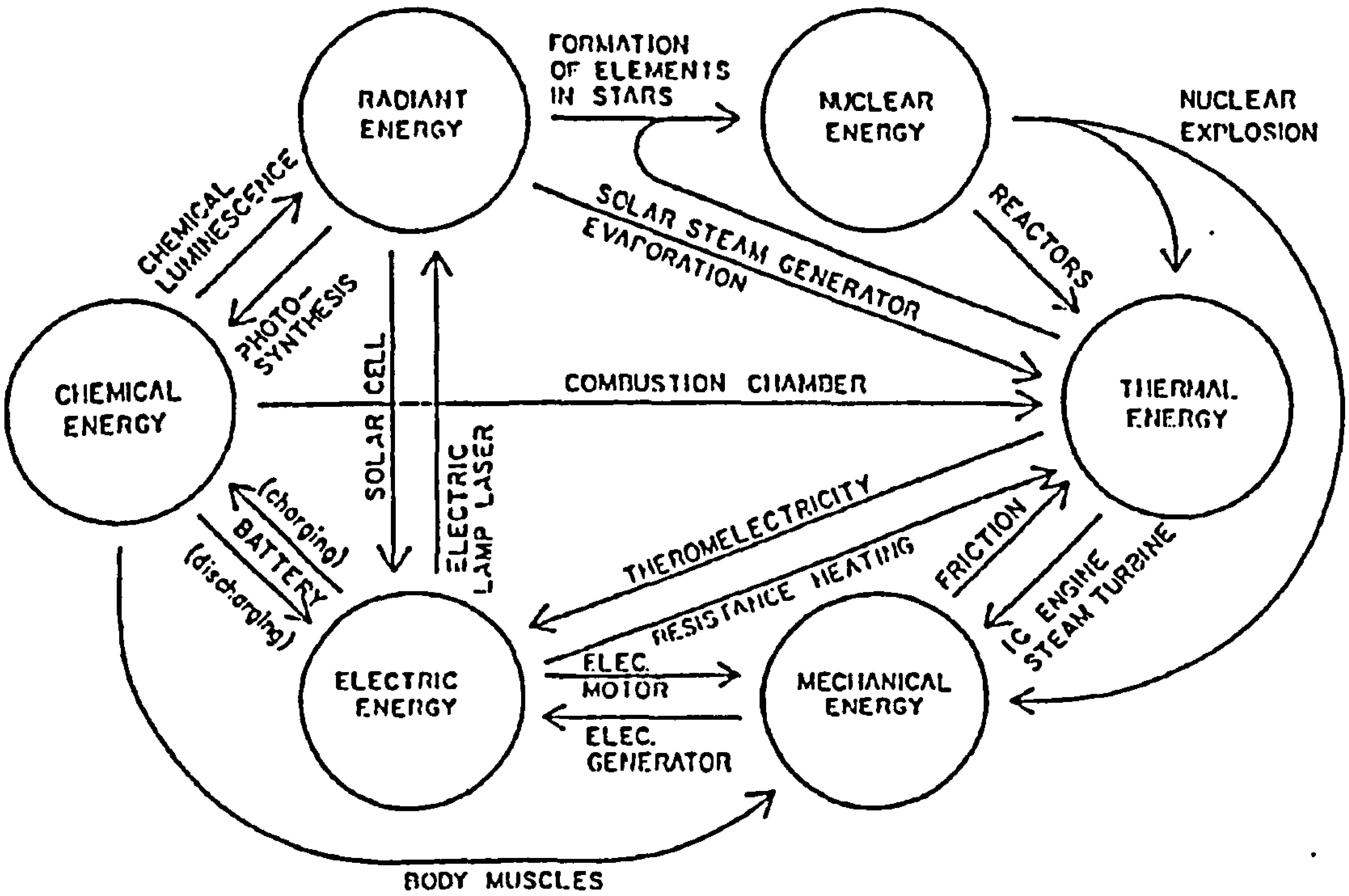
As the water moves to a lower elevation (a lower energy state) it releases energy in the form of work.

3.2.3 Energy conversion

Energy can be converted from one form to another through mechanisms and means that have been developed through engineering. This conversion is essential in order to produce the needed form of energy for a specified end use from all available energy in all its forms.

Some forms of energy that are important from an engineering point of view are presented in figure (3.1). Kinetic and potential energy forms both constitute mechanical energy. The major transformation of energy between one form and the other by means of mechanisms available with existing technologies are shown in the figure as arrows indicating the direction of energy transformation and labelled with the available energy conversion means. For example, the diagram indicates that nuclear energy must first be converted to thermal energy and then to mechanical energy, finally to produce electrical energy, since no technology currently exists for converting nuclear energy directly to electrical energy.

Figure (3.1) Interconnecting Energy Forms



Source: Henry et al., 1980

3.2.4 Heat and Work

"Heat and work are manifestations of energy transfer in a process. Contrary to a common belief they do not describe the energy content of a system, but rather the energy transfer during a process through which the system is being subjected" (Henry et al., 1980, p 23).

When energy in the form of heat is added to a body, the content of energy of the system will rise, causing a rise in temperature of the body or a change in its physical state or a phase change. A change of phase will mean a higher energy state of the body such as the change from liquid to vapour that takes place in water when energy is added to it in the form of heat.

"Heat and work released within a system are interchangeable. It is theoretically possible to completely convert work produced into heat while only a fraction of heat produced can be converted to work" (Henry et al., 1980, p 23).

3.2.5 Fuels

Our energy resources consist of material in which energy is stored in a number of different forms. When the energy stored in a given material, it is converted conveniently to other forms needed by our social and industrial applications. The materials are considered fuels (World Energy Council, 1992).

Natural gas is a fuel. The energy in natural gas is in the form of chemical energy and is released or converted to thermal energy upon the combustion of the gas. The combustion process can be expressed as follows:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

As the high energy bond between the carbon and hydrogen atoms is broken, a lower energy bond is formed between Oxygen and Hydrogen atoms and Oxygen and Carbon atoms (Oxidation). The excess energy is released in the form of heat and thus converted to thermal energy.

Thermal energy is needed and used in a variety of ways to achieve desired goals. There are two most common ways in which thermal energy is utilised. The first is for direct heating such as for space heating, and industrial process as heat used for annealing, melting, drying or other purposes. The second is where it enters a process and undergoes a further conversion to another form as, for example, mechanical energy through steam and gas turbines or internal combustion engines (World Energy Council, 1992).

3.2.6 Energy Losses

Energy always undergoes a number of transformations (conversion of form) through means made available by current technologies to reach the form, or go through intermediate forms, in which it is needed in the final application or to produce the required end work effect. These transformations, however, normally entail losses in the form of energy converted to undesirable forms, or energy not utilised. An example is the loss of thermal energy dissipated from the internal combustion engine; the useful intended energy in this particular conversion process is the mechanical form.

Another example of energy loss is the process of converting electrical energy to light. Only a fraction of the electrical input is converted to light (the desired end use of the energy). The remaining energy is converted to other, undesired, forms of energy such as radiant heat and light in the invisible spectrum (Henry et al., 1980).

The limitations on interchangeability of energy forms are governed by the first and second laws of thermodynamics. Since the technologies used for the conversion influence the losses, they are an essential part of any energy utilisation process (Henry et al., 1980).

3.2.7 Energy Efficiency

The previous subsection demonstrated the concept of energy losses, whereby part of the original energy input is converted to unwanted forms that cannot be used, and only a fraction is converted into the form needed to accomplish the required task. The ratio of useful energy output to the energy input is called efficiency.

The efficiency of a conversion system depends on several factors including the initial and final forms of energy, and the technology used. Figure (3.2) illustrates demonstrated efficiencies in several energy conversion schemes. For electrical energy generation, for example, it is a rule of thumb that it takes approximately 10,000 British Thermal Units (BTU) of input chemical energy to produce one kilowatt-hour or 3412 BTU of electrical output giving process efficiency of approximately 34% (Henry et al., 1980).

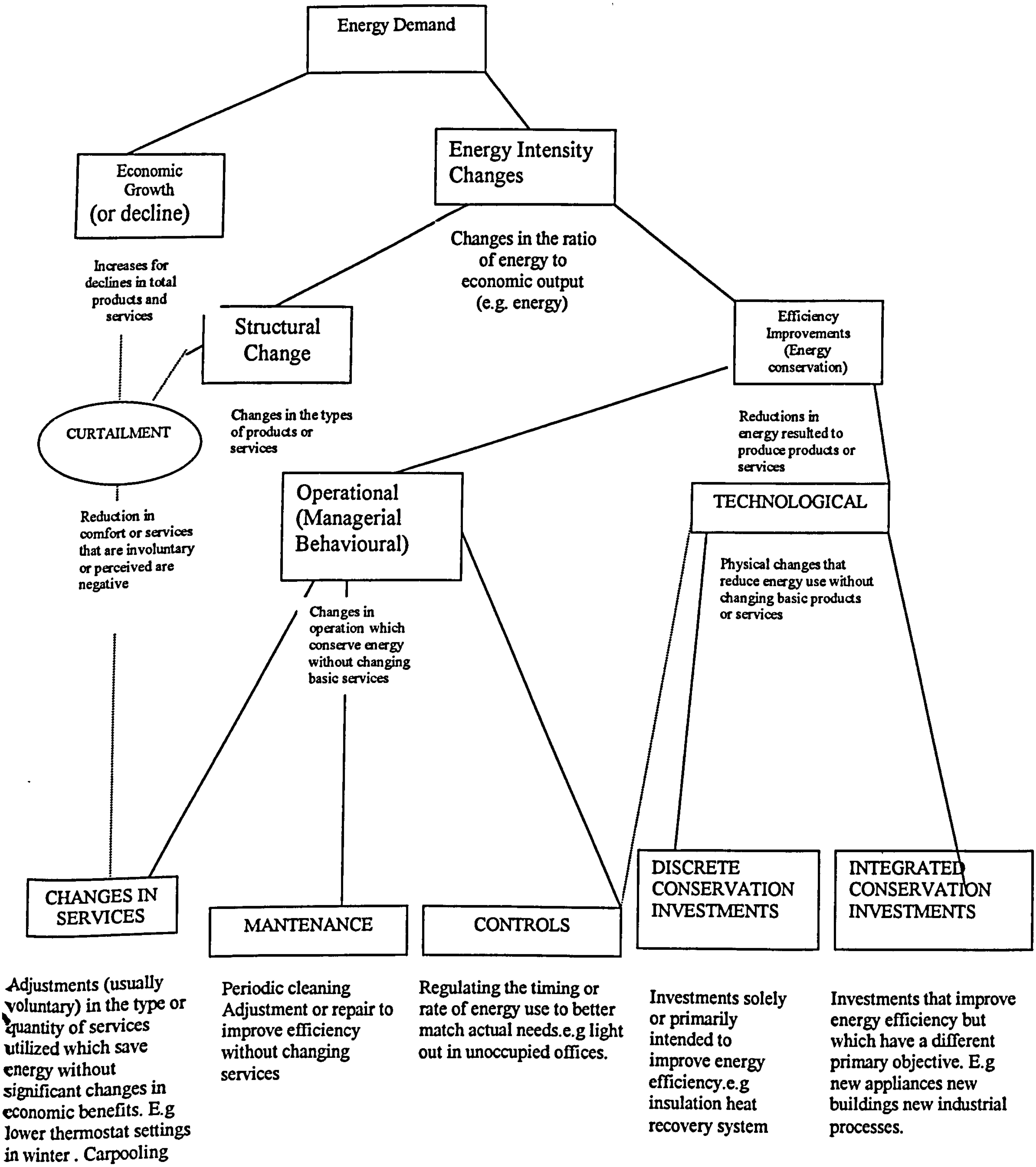


Figure (3.2) Energy Demand and Efficiency Terms and Definitions

3.2.8 Energy Intensity

In order to quantify or evaluate the changes in energy efficiency, these changes have to be converted to a standard reference frame by eliminating the effect of changes in the level of services or output. On a sectoral level these output levels are quantified in the economic output. The changes in levels of output are reflected in fluctuations of the economic output or sectoral activity. Dividing the energy consumption in a given sectoral by the economic output of that sector gives a parameter that measures the unit energy used per unit economic output, Energy Intensity (EI), which is considered an important indicator of energy efficiency (World Energy Council, 1993).

For a given country, energy intensity is usually defined as the ratio of:

$$\frac{\text{Total Primary Energy Consumption}}{\text{Gross Domestic Product (GDP)}}$$

If used properly, this indicator can provide a tool for comparing energy efficiency development on an international level. By observing the trend of EI over time, conservative conclusions can be drawn on the efficiency progress of nations relative to a world picture. Careful considerations must be made before this definition is used to calculate the energy intensity in order to avoid errors caused by several factors, as follows:

1. Differences in GDP composition will influence the intensity of energy due to a larger share of a specific economic sector such as a more energy intensive industrial nature. The industrial sector in developing countries, for example, is mostly based on low value added products and tends to be more energy intensive. This is reflected in an observed and projected steady increase of energy intensity. Therefore, trends in energy intensity do not necessarily reflect changes in energy

efficiency, but may be reflecting shifts in GDP mix towards more energy intensive activities.

2. Choosing an appropriate denominator which accurately reflects sectoral and overall economic output requires care. If the denominator is expressed in monetary terms, data must be converted into a single currency. Normally the US dollar is used for international comparisons. In many developing countries, there can be more than one exchange rate against the US dollars. In some nations, a rate is specified by the government as the official rate and a second will be the market exchange rate, with the latter reflecting the realistic purchasing power of the currency. In converting the GDP figures to a single currency (US dollars or EURO, etc.) caution must be exercised not to use a rate that does not accurately reflect the market value of the currency and the GDP should be converted into real purchasing power parities (PPP) if correct energy intensity indicators are to be obtained.

   Shadow pricing methodology as explained by Munasinghe et al. (1982) can also be used whereby a conversion is used to remedy or correct market distortions which result from certain monetary or fiscal policies in developing countries. This factor is applied to certain distortable elements of the pricing mechanism such as foreign currency, exchange rate, prices of tradable goods etc.

3. Inflation which reduces the value of currency versus finished goods will cause an increase in the value of the expressed GDP with time over and above the actual GDP growth. To compensate for the effect of inflated GDP due to monetary inflation, the GDP value must be deflated using an appropriate deflator to give the value in terms of constant currency at a base year (1985 US dollars for example). Dividing the energy consumption figures, a physical quantity, by the constant dollar GDP will yield the required results.

4. Energy consumption figures in most developing countries do not include non-commercial energy production, which constitutes about 20-30% of the total energy consumption. This will cause an underestimation of the energy intensity.

5. The technological base starting points for different countries may be different. Less developed countries tend to rely more on older technologies which are low on energy efficiency. Marginal improvements in technology can result in marked increase in efficiency and will result in strong rates of energy intensity decline over time. In contrast, a developed nation may be already implementing a high-tech level and energy efficient industrial installations and will not demonstrate as strong a decline in energy intensity as in other less developed countries, where the potential for energy efficiency is still high.

In addition, country specific factors such as climate, distances between cities, size of homes, and social and cultural characteristics will influence the level of energy intensity and will impose further limitations on international comparisons.

These points must be carefully considered if energy intensity rates of change are to be used as an effective tool for measuring energy efficiency through comparisons of changes over time for a single country and among different countries.

3.2.9 Energy Elasticity

From an economic point of view, the elasticity of energy (demand/ supply) is defined as the percentage of energy (demand/ supply) growth (change) for a given change in price (price elasticity or income elasticity) (World Energy Council, 1992).

In developing countries, the elasticity of demand for energy tends to be much higher than in the developed countries. This is possibly explained by richer countries spending a smaller proportion of their GDP on energy. The demand for energy is thus less sensitive to price. It may also be influenced by changes in structural factors (government control and ownership), urbanisation (which increases electricity and fuel demands), and industrialisation. High elasticity of demand value will still be expected in the future because the economies of developing countries are still far from maturity (Preston, et al., 1992).

3.3 Energy Conservation and Rational Use of Energy

The science of thermodynamics views energy conservation and efficiency within the bounds of physical laws and processes. The law of conservation of energy, for instance, states that energy cannot be created or destroyed, only transformed. However, such transformation is never ideal or perfect but rather it involves inescapable "losses" in different forms (Darmstadter et al., 1983 p 34).

"Conservation means different things in different situations. In its ethical, equity, or environmental dimensions, conservation has to do with moderation as an inherently worthy pursuit. In the face of possible resources limitations and environmental uncertainties, it is nothing more than a commitment to equal justice under the grudging law of nature" (Darmstadter et al., 1983 p 34).

On the other hand, engineers are concerned with efforts to develop technology and materials boosting the yield of a given amount of energy, improving the efficiency with which energy is delivered, and the cost of achieving such an improvement (Darmstadter et al., 1983 p 34).

This draws attention to the fact that conservation must be carefully evaluated as an economic proposition. Viewed from that perspective, energy conservation means the most economic application of energy in the production of goods and services or in their use by ultimate consumers. It is of no benefit simply to replace energy by something else (materials or labour) that costs more. There has to be some overall economic benefit. Darmstadter et al., (1983) give some examples: "An aluminium manufacturer may be able to lower overall production costs by introducing a process that lowers the energy requirement of an ingot produced. A homeowner may succeed in reducing heat losses by adding insulation that costs less than the resultant savings on a year's utility bills" (p 35).

Both cases signify the importance of using energy rationally, including the exploitation of energy saving opportunities, which, if foregone, mean unnecessary expenses.

Rational use of energy is concerned with both supply and demand. On the supply side, it deals with increasing the efficiency and economy of energy production or choice of conversion technology. In the case of the demand side, it is concerned with conservation, demand side management or use optimisation. Elkarmi (1994), for instance, estimates that only a small percentage of total energy consumption in the Arab countries is used rationally. The reasons for this are that rich, oil-producing countries subsidise the cost of energy use while poor, oil-importing countries do not have the financial resources to improve the efficiency of energy use and usually they acquire "obsolete" energy intensive processes. Only countries in the middle, such as Jordan, have rational energy use programmes.

An important implication for the conservation of energy which is often forgotten is an environmental impact. In a simplistic way the amount of energy saved (or not consumed or burned) means a corresponding amount of gas emissions not emitted to the atmosphere. This is why the Kyoto Protocol called for 38 industrial listed countries to reduce their emissions of greenhouse gases by an average of at least 5% below their 1990 level by the year 2012.

3.4 Efficiency of Energy Use

3.4.1 Background

The utilisation of energy with high efficiency is essential in any application, for several reasons. First and foremost, it contributes to energy resource conservation and hence prolongs the life of limited natural resource reserves and reduces environmental pollution. On the other hand, it is essential for reducing the cost component of energy and contributes to a more economic and cost effective output in the economical sectors in general and industrial sectors in particular. Industrial sectors are the largest energy resources consuming sectors. Despite extensive efforts and plans undertaken in the past two decades to enhance the efficiency of energy utilisation, there still remains large areas where further efficiency improvements can be achieved in industrial applications, as well as other economic sectors. Such situations include energy efficiency improvements requiring large investments or cases where decision-makers lack a proper understanding of the importance of such measures.

These potential areas where further efficiency improvements can be achieved include: energy saving lighting, efficient motors, adjustable speed drives, thermal energy storage, effective insulation, window shading, passive architecture. Furthermore, introducing an energy management system in industrial plants and buildings can have a significant impact on energy efficiency.

Efficient energy sector management and optimal exploitation, particularly in industry, require a multi-disciplined knowledge base, which includes expertise in economics, management, thermodynamics, heat transfer, fluid mechanics, electricity and control theories. All of these sciences are considered essential for the development and implementation of effective, efficient and economic means of energy resources exploitation. At present, the various disciplines are used by adopting integrated strategies and policies for exploiting, managing and conserving energy (World Energy Council, 1995).

The industrial sector is the largest energy consumer globally, as its consumption in 1992 accounted for 43% of total primary energy consumption in the world. During the period (1971-1992) the growth rate of energy demand by the industrial sector was about 1.9% (World Energy Council, 1995).

Innovative energy management programs directed to wards energy conservation are needed as a measure to achieve energy conservation, especially in energy-intensive industries. Some countries have issued regulations for mandatory establishment of an energy management department and the appointment of a senior manager to run it, in industries with consumption levels exceeding some specified value. Monitoring energy consumption per unit of product (expressed in MJ/tonne of iron produced), for example, provides an effective tool for evaluating energy efficiency improvement.

Reduction in overall energy intensity has been achieved as a result of structural changes in the economies of IEA member countries and increased levels of energy efficiency (OECD, 1987).

Each factor made important contributions to lower energy intensities, although by different means. The relationship between them and their contribution to overall efficiency of energy is depicted in figure (3.2) (OECD, 1987).

The main theme of figure (3.2) is that energy demand is directly related to and dependent on economic growth and changes in energy intensity. As for energy intensity, which is much more related to our subject matter of energy efficiency, the figure shows that changes in energy intensity result from improvements in efficiency or energy conservation. Energy conservation can be achieved either by technological changes or operational activities.

As for the global trends related to energy efficiency improvements in the industrial sector (including cement industry), the World Energy Council (1995) reports that many developing countries are now striving to support private and public sector efforts to obtain world-class technology for industry. A number of factors, however, hinder such efforts. These include distorted energy prices and a lack of well-functioning markets. Policies and practices in industrialised countries that discourage the transfer of technologies as well as the knowledge and skills needed to install and operate them also impede the efforts of developing countries to improve energy efficiency.

As examples of policies to improve energy efficiency in the industrial sector, the report cites:

- Establishing goals for industrial energy saving as has been done in Japan and Sweden among others;
- Supporting national and international standards organisations, which set industry consensus standards for many industry products and equipment, develop test procedures for products, or establish performance-related labels. These standards, procedures, and labels have played a valuable role in improving the energy and other characteristics of industrial products and processes;
- Improving the quality and availability of information about industrial energy efficiency through governments, trade associations, or other appropriate bodies. It suggests that if significant efforts were made at an international level to support energy efficiency in developing countries and economies in transition, the world could embark on a major effort to increase the efficiency of its energy system.

Preston et al. (1992) stated that defining, measuring and devising specific programs to encourage energy efficiency improvement are not easy tasks. There is no universally accepted definition of energy efficiency improvement. They viewed energy efficiency in general as a qualitative term that refers to the relative thrift or extravagance with which services are provided with an energy input that is small, relative to a fixed standard or perceived normal input. Thus, becoming more energy efficient means reducing the energy input required to provide a given service, or providing increased or enhanced services with less than a corresponding increase in the amount of energy required.

This brings us to the concept of energy intensity. Preston et al. defined energy intensity in the manufacturing sector as the quantity of energy required to produce a unit of output, or more precisely, the ratio of offsite-produced energy consumption to output measured in constant dollar value of shipments (Preston et al., 1992).

However, they pointed out that a decrease in energy intensity could not necessarily be directly interpreted as an increase in energy efficiency. While acknowledging that improved energy efficiency does reduce energy intensity, they pointed out that a change in national energy intensity can result from factors unrelated to energy efficiency, such as change in the mix of GDP. Within a single industry, however, an inverse relationship can be expected between changes in intensity and efficiency.

3.4.2 Future Trends of Energy Demand and Efficiency in the Industrial Sector

Several factors determine the future energy demand level and the efficiency of its utilisation (the source and use of energy - for example China has a high dependency on coal stoves and boilers whereas gas stoves and boilers are significantly more efficient (World Bank, 1995). These factors are the rate of economic growth and energy intensity (OECD, 1987).

Energy intensity is in turn dependent on two factors: the economic changes that take place and the rates of energy utilisation efficiency improvement in any given country.

The International Energy Agency (OECD, 1987) states that energy utilisation efficiency is governed by:

- Energy cost and availability
- Energy conservation technology costs and availability
- Energy conservation services availability

This refers to the availability of energy and technological resources required by energy consumers for adoption and implementation of effective energy conservation policies. These resources include the availability of information on equipment and machine efficiencies, and the availability of knowledge of energy conservation technologies.

Moreover, the turnover of capital stock and economic growth will determine the size of financial resources available for investment in more energy efficient systems and will dictate governmental economic polices which will, in turn, have an effect on future energy demand.

In the industrial sector in particular, a growth in energy demand is expected but at a lower rate than that of the national level and other sectors. This is due to the slow growth rate of the industrial sector, the rapid growth in other sectors, especially in the service sector, and a reduction in industrial sector energy intensity as a result of a general shift to less energy intensive industries (i.e. industries with lower energy to added value ratios). It is also due to improved and more efficient production technologies and investments in conservation of energy equipment as well as more efficient operating procedures with the introduction of computers and advanced control systems (OECD, 1987).

3.5 Energy Consumption in Jordan

3.5.1 Energy and Economy

The cost of energy is considered to be a main burden on the Jordanian economy. In 1995 expenditure on energy amounted to about 7% of the Gross Domestic Product (GDP), 31% of total exports value, and around 13% of total imports value (Ministry of Energy and Mineral Resources, 1995).

The following table (3.1) shows the development of energy cost as a percentage of GDP, total exports and imports values during the period (1980-1995).

Table (3.1)

Cost of Energy as a Percentage of GDP,

Exports and Imports Values (1980-1995)

(%)

Year	Exports	Imports	GDP
1980	102	17	12.4
1983	126	19	14.6
1985	76	18	10.3
1986	49	13	5.5
1987	60	16	7.2
1988	41	13	6
1989	47	21	9.6
1990	42.5	17.4	11.7
1991	45.3	18.6	11.1
1992	37	14	9
1993	44	14	9
1994	33	15	8
1995	31	12.7	7.2

Source: Ministry of Energy and Mineral Resources, Annual Reports.

As can be seen from table (3.1), the cost of imported energy as a percentage of exports decreased from 102% in 1980 to 49% in 1986, reflecting the decrease in crude oil prices, which increased slightly in 1987. Since then, although it has fluctuated slightly, it has remained less than 50 %.

The average value of energy imports as a percentage of total import value was about 16% during the period 1980-1995. The value of energy imports as a percentage of GDP was 12.4% in 1980 and decreased to 5.5% in 1986. However, the average energy cost as a percentage of GDP during the period 1980-1995 was about 9%.

3.5.2 Energy Consumption

(A) Primary Energy Consumption

During the period 1974-1983, the growth rate of primary energy consumption in Jordan amounted to around 15% and GDP growth was about 11% per annum. These growth rates are considered to be very high and could be attributed to the high growth in mining and manufacturing industries including phosphate, cement and potash. Moreover, other factors such as the increase in workers' remittances (Jordanian workers in the Gulf countries), and the increase of the exports of Jordanian products both contributed to the above mentioned high growth rates in energy consumption and economy.

Primary energy consumption decreased to about 3.5% per annum during the period 1983-1989, and the GDP growth rate also decreased to about 3.4% per annum during the same period. The decrease in energy consumption was partially due to the adoption of energy conservation measures by the Jordanian government and also due to adjustment of prices of petroleum products to reflect international prices to some extent (Ministry of Energy and Mineral Resources, Annual Reports).

In 1991, the primary energy consumption in Jordan amounted to 3,275 thousand tonnes of oil equivalent (ttoe), representing a 1% decrease from 1990 levels. One thousand tonnes of oil equivalent has an energy content of 44 TJ or is equivalent to 12.2 GWh. The main reason for this decrease was the adverse impact on the Jordanian economy of the Gulf Crisis.

In 1992, primary energy consumption amounted to around 3,805 ttoe, a growth rate of about 16% over the 1991 level, which is attributed to the following factors:

- Increase in number of population due to the Gulf Crisis;
- Growth in economic activities of the industrial, tourism and construction sectors.

In the years 1993, 1994 and 1995, the growth rates of energy consumption amounted to 3.6%, 5.4% and 5.8% respectively. These moderate growth rates reflect the improvement in the efficiency of energy use and the enhancement of energy management in general (Ministry of Energy and Mineral Resources, Annual Reports).

Table (3.2) shows the development of primary energy consumption by sector during the period 1974-1995.

Table (3.2)
Sectoral Primary Energy Consumption (ttoe*)

Year	Transport	Industry	Household	Electricity	Refinery	Others	Total	Growth (%)
1974	287	93	96	110	72	110	768	--
1980	665	276	198	303	137	260	1839	15.7
1983	922	325	232	540	205	362	2587	12.1
1985	972	338	245	692	191	405	2843	4.8
1986	939	355	263	748	163	408	2876	1.16
1987	957	368	270	834	185	417	3031	5.39
1988	969	381	293	829	201	413	3086	1.81
1989	1069	355	289	868	194	360	3135	1.58
1990	1077	394	304	920	208	405	3308	5.5
1991	1010	393	343	957	188	384	3275	(1.0)
1992	1093	488	463	1145	208	408	3805	16.2
1993	1130	512	426	1221	201	451	3941	3.6
1994	1157	514	442	1381	210	452	4156	5.4
1995	1254	541	449	1474	216	466	4400	5.8

Source: Ministry of Energy and Mineral Resources, Annual Reports.

* ttoe is approximately 0.25 GWh

(B) Electricity Consumption

Table (3.3) shows the electricity consumption by sector during the period 1985-1995.

Table (3.3)
Electricity Consumption by Sector (GWh)

Year	Industry	Household	Water Pumping	Others	Total	Growth (%)
1985	903	655	275	318	2151	-
1988	1040	821	522	377	2760	8.7
1989	1094	841	565	410	2910	5.4
1990	1189	874	545	481	3089	6.2
1991	1181	928	548	484	3141	1.7
1992	1342	1074	688	572	3676	17
1993	1449	1192	702	638	3981	8.3
1994	1519	1317	768	726	4330	8.8
1995	1677	1421	885	795	4778	10.3

Source: Jordan Electricity Authority, Annual Reports.

The following table (3.4) shows the electricity consumption by large industries during the period 1990-1995.

Table (3.4)
Electricity Consumption by Large Industries (GWh)

Industry	1990	1991	1992	1993	1994	1995
Cement	162	186	198	220	217	223
Phosphate	101	92	110	110	71	108
Fertiliser	151	145	147	127	170	187
Potash	209	207	207	214	251	281
Refinery	73	63	77	84	85	85
Total	696	693	739	755	794	884
Total Industry	1189	1181	1342	1449	1519	1677
Percentage of Large Industries to total Industry(%)	59	59	55	52	52	53
Percentage of cement to total Industry (%)	13.6	15.7	14.8	15.2	14.3	13.3

Source: Jordan Electricity Authority, Annual Reports.

Table (3.4) shows that 5 large industries consumed more than 50% of total industrial electricity consumption during the period 1990-1995. It also shows that the cement industry in Jordan consumed an average of 14.5% of total industrial electricity consumption during the period 1990-1995.

3.5.3 Energy and Electricity Intensities

Table (3.5) shows the development of energy and electricity intensities (total and for the industrial sector) during the period 1985-1995.

Table (3.5) shows that the total energy intensity in Jordan is very high in comparison with other countries, which reflects the high potential for improving the efficiency of energy use. The lowest value was recorded in 1988 due to high growth of GDP in that year. Although there is no trend in the development of energy intensity during the period 1985-1995, but the average energy intensity during that period was about 1.6 toe per 1000 JD (GDP). As for the industry, the energy intensity recorded its lowest value in 1989 (1.26) due to high growth in industrial value added, which amounted to around 20% of (GDP). The same argument is also valid for industrial electricity intensity, which amounted to around 3879 kWh/1000 JD (value added) in 1989.

Table (3.6) shows a comparison of energy consumption per capita and energy intensity for selected countries. The table shows that total energy intensity in Jordan is high in comparison with other countries. As for energy consumption per capita, Jordan's figure is about one-tenth that of the USA or Canada.

Table (3.5)

Energy and Electricity Intensities (1985 - 1995)

Indicator	1985	1988	1989	1990	1991	1992	1993	1994	1995
Gross Domestic Product (million JD, 1985 prices	1880	2183	1890	1908	1943	2255	2387	2527	2675*
-Industrial** value added (million JD, 1985 prices)		235	282	288	275	307	309	334	361*
-Total energy consumption (ttoe)	2843	3086	3135	3308	3275	3805	3941	4156	4400
-Total electricity consumption (GWh)	2151	2760	2910	3089	3141	3676	3981	4330	4778
-Industrial primary energy consumption (ttoe)	338	381	355	394	393	488	512	514	541
-Industrial* electricity consumption (GWh)	903	1040	1094	1189	1181	1342	1449	1519	1677
-Total energy intensity toe/000JD(GDP)	1.51	1.41	1.66	1.73	1.69	1.69	1.65	1.64	1.64
-Total electricity intensity kWh/000 JD (GDP)	1144	1264	1540	1619	1617	1630	1668	1713	1786
-Industrial energy intensity toe/000 JD (value added)		1.62	1.26	1.37	1.43	1.59	1.66	1.54	1.50
Industrial electricity intensity kWh/000 JD/(value added)		4426	3879	4128	4295	4371	4689	4548	4645

Source:Ministry of Energy and Mineral Resources, Annual Reports

* estimated
** Mining and Quarrying

Jordan Electricity Authority, Annual Reports.

Table (3.6)
Comparisons of Energy Intensities and
Energy Consumption per Capita in Selected Countries (1993)

Country	Energy Intensity Kgoe*/$GDP	Energy Consumption per Capita toe**
Japan	0.108	3642
France	0.185	4031
Switzerland	0.106	3491
Turkey	0.333	983
Spain	0.196	2373
Greece	0.303	2160
UK	0.227	3718
Ireland	0.222	3016
USA	0.323	7918
Canada	0.417	7821
Egypt	0.833	539
Tunisia	0.345	582
Israel	0.196	2607
Jordan	0.714	766

Source: World Bank (1995).

3.6 Energy Conservation and Rational Use in Jordan

3.6.1 General

The flow of material and energy in industrial processes behaves in the manner presented below in figure (3.3). It can be seen that in order to increase profitability, it is the duty of the industrial management to reduce the cost of industrial inputs as much as possible by reducing raw materials and energy losses and recycling them.

* Kilograms of oil equivalent
** Ton of oil equivalent

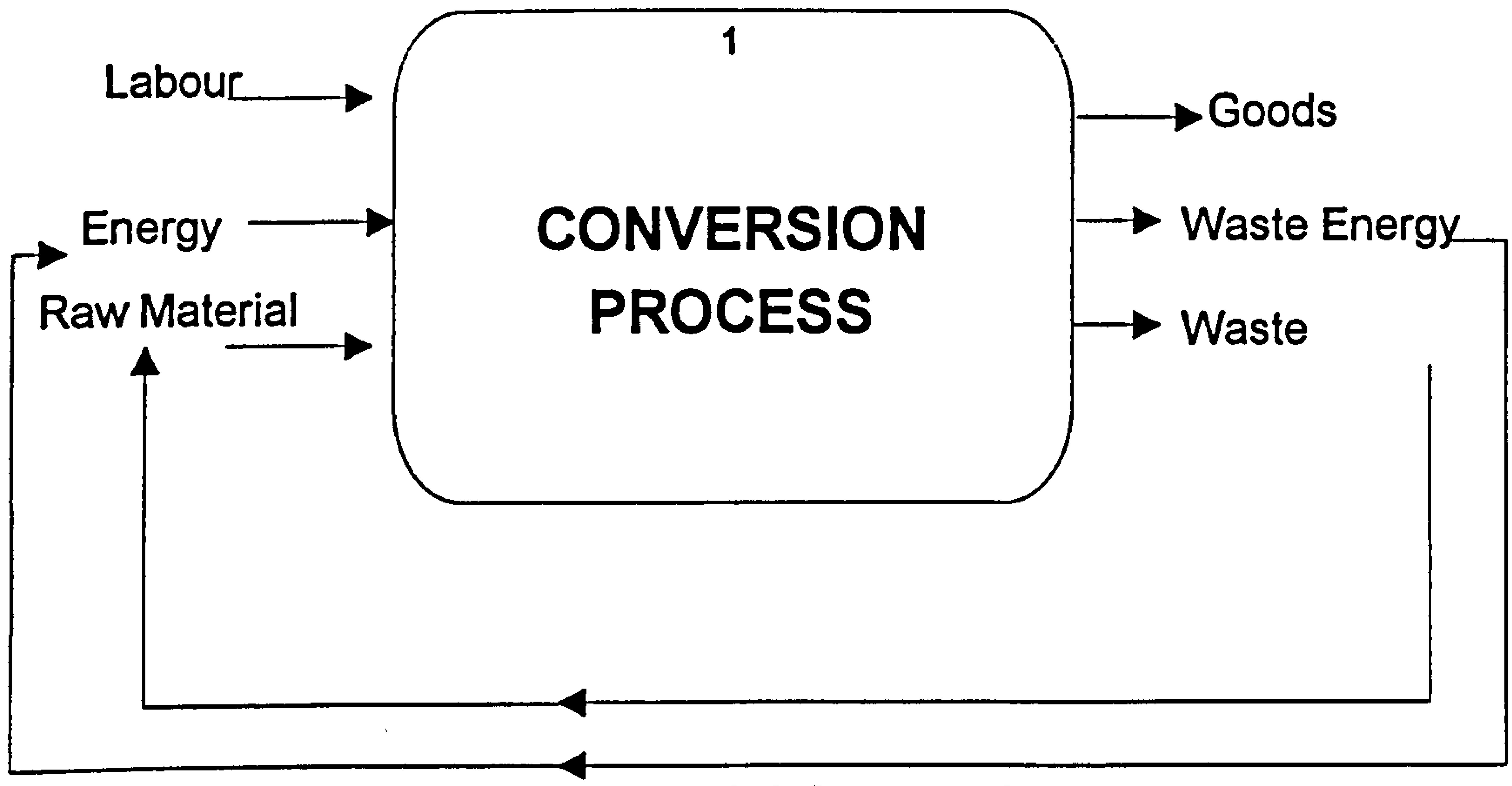


Figure (3.3) Recycled Industrial Conversion Process

Source : Chiogioji (1979).

Industrial energy expenditures can be reduced either by increasing the efficiency of energy utilisation or by recycling wasted or exhausted energy. In order to specify the areas where significant energy cost reductions can be achieved, the following issues must be investigated:

1. Identify areas with potential for energy utilisation efficiency gains.
2. In the identified areas of potential, identify the alternative processes or activities that can lead to more efficient use of energy (Chiogioji, 1979).

According to Chiogioji (1979), there are several factors, which affect energy use:

1. Capital and fuel cost;
2. Operation and maintenance cost;
3. Industrial process technology adopted;
4. Equipment capability and reliability;
5. Fuel supply availability;
6. Job requirements.

3.6.2 Principles of Conservation of Energy

Rational use of energy means the optimal usage of energy or the increase in energy usage efficiency (World Energy Council, 1995), which can be measured by the following two methods:

A) Technical Efficiency

Technical efficiency defined in the first law of thermodynamics as the ratio of the amount of energy that is utilised to produce useful work to the total energy consumption.

B) Economic Energy Efficiency

Economic energy efficiency, referring to the use of energy to produce a unit of output at a minimum cost due to the use of cheaper energy sources.

In order to achieve higher efficiency, according to Chiogioji (1979), several measures can be adopted, including the following:

1. - Housekeeping Measures

Industrial installations can adopt measures, at zero or low cost, that result in significant reductions in energy consumption, and may include improved operation, training and better maintenance procedures.

2. - Equipment and Process Modifications

This aims at making changes in the applied technology with limited expenditure, resulting in more efficient use of energy.

3. - Integrated Operations

This is accomplished through a review of current production practices and operating procedures where a total perspective is used for achieving an overall, company-wide, improved energy efficiency, rather than focusing on individual departments. This approach usually involves major changes and large financial investments.

The last two measures require financial expenditures, whereas the first only involves sound planning and serious managerial effort for achieving higher energy efficiency. The following are the prerequisites for establishing such a management directive:

- A basic understanding of energy principles and its use in industrial installations.
- Conducting comprehensive surveys to measure all energy inputs and outputs during a given period and the identification of equipment associated with large energy consumption.
- Creating and communicating a plan of action.
- Setting targets for unit energy consumption in all industrial units.
- Managing and controlling energy use against the targets (Chiogioji, 1979).

3.6.3 Government Measures for Promotion of Rational Use of Energy in Jordan

The Ministry of Energy and Mineral Resources (MEMR) has adopted policies and measures to improve energy efficiency, which have been effective in reducing the financial burden of imported energy on Jordanian economy:

A) Proper Pricing Policies

This policy seeks to reflect the actual energy cost to consumers. Some subsidy provisions have been retained, however, for limited income groups.

B) Free Energy Audit

The Ministry offers a service to industries at no cost where studies in the field of energy utilisation and efficiency enhancement are conducted at the request of the consumers.

C) Legislation and Regulations

Policies and legislation have been introduced aimed at improving energy efficiency. Examples include setting speed limits for vehicles on highways, imposing high duties on energy intensive equipment and promoting the use of thermal insulation in buildings.

D) Information Dissemination and Consumer Awareness Programmes

Educational and cultural programmes are conducted for energy consumers, in order to promote more efficient use of energy.

E) Training

The Ministry provides training opportunities for employees involved in energy related fields and introduces them to means of improving energy systems efficiency. Moreover, the Ministry organises training programmes (seminars and workshops) in the field of energy management in industrial companies.

F) Advisory Services

Advisory offices have been set up across the country to offer technical guidance to energy consumers and promote more energy-efficient practices and appliances.

3.6.4 Obstacles to Energy Conservation

There are several obstacles that hinder the implementation of energy conservation programmes, including the following:

A) Improper Energy Pricing Policy

Jordan suffered from the absence of a clear policy on energy pricing before the creation of MEMR in 1984, as energy was sold to consumers generally at a price below its actual cost. This caused wasteful practices in the use of energy and inhibited the adoption of energy-conserving practices by consumers. A policy has now been adopted which is designed to bring prices in line with actual costs.

B) Lack of Awareness of the Potential Benefits of Adopting Energy Conservation Policies.

Energy management science is relatively a new discipline and it is crucial that energy utilisation and conservation technologies are properly publicised and transferred, particularly to energy intensive industries. Whilst energy has been relatively cheap industry has preferred to address other financial issues (for example, in the UK labour costs, which are often an order of magnitude greater, Marmont, 1995). It is essential to raise awareness of the potential benefits of adopting appropriate energy management practices.

C) Inability to Define Energy-Related Problems

This is a direct consequence of the lack of awareness of the potential benefits of efficient use of energy, as described in the preceding paragraph. Staff awareness is also vital see for example Energy Efficiency Best Practice Programme GPCS327.

D) Inability to Perform Sound Economic Evaluation of the Technical Options

Many industrial institutions, especially small and medium scale industries, lack the technical and financial capabilities for evaluating energy conservation projects and selecting the optimal economic option.

E) Absence of Energy Accounting in Enterprises

Energy, which is a component in product cost, is not given its due importance as a basic and major element in industrial production costing, especially in small and medium scale industries. This leads to a lack of awareness of the contribution of energy to running expenses and the potential savings that can be realised from energy- saving measures and practices.

3.6.5 Conservation of Energy in Jordanian Industry

Several studies have been commissioned to promote conservation of energy in the Jordanian industry. These studies included relevant data and preliminary reports on efficiency improvement measures. Detailed and comprehensive studies by Bechtel Inc. (1985) and RCG/Haggler, Bialy Inc. (1990) investigated efficiency enhancement in the main industries in Jordan, namely, petroleum refining, power generation, fertiliser, steel, cement, phosphate, potash, glass, ceramics, and bricks. The studies were preliminary audits investigating energy management practices, if any, as well as potential energy saving measures.

Their findings suggest that the following measures will enhance energy use efficiency without any additional capital expenditure:

1. Modifications in operational practices e.g. better organisation of processes to ensure that batch operations requiring energy intense equipment are concentrated into short periods.
2. Administrative action aimed at educating and training of staff in the area of energy utilisation. The Staff is then encouraged to switch off unnecessary equipment.
3. Better energy monitoring, targeting and management.

In addition, several measures that could have a significant impact on efficiency, which require capital expenditures have been identified as follows:

a. Heat recovery from fired heater exhaust stacks for:
   - Air preheating;
   - Steam and power generation;
   - Fuel heating ;
   - Raw material heating.

b. Improving heat utilisation from process streams through better heat exchange.

c. Optimal process control utilisation.

d. Optimal thermal insulation utilisation.

e. Optimal electric power utilisation.

f. Process modifications.

However, these studies were general and not detailed. This was dictated by their terms of reference. Therefore, the investigations focused on readily identified areas of efficiency improvement or energy conservation. They concentrated on housekeeping measures, as they did not rely on detailed audits. In essence these studies can be considered as preliminary or "eye-openers" which must be followed by detailed plant-by-plant studies.

3.7 Related Previous Research and Literature Review

This section reviews previous research and literature available on the subject of the thesis as well as other related relevant issues. This step is needed before venturing into the research in order to verify if others have covered this work and to provide a secure basis for the later chapters. The search scope covered technical measures relating to energy in the cement industry, fiscal instruments applied to energy in the cement industry, previous investigation of using statistical techniques and analysis in cement industry and other highly energy intensive industries in several world countries and previous investigations of energy management.

3.7.1 Technical Measures relating to Energy in the Cement Industry

Mullick and his co-authors (1994) assessed the need for energy efficiency and monitoring of cement plant operation in India, where specific energy was high (Ishiguro and Akiyama, 1995). They concluded that greater attention needed to be given to management or good house keeping approaches which include an integrated approach for energy management involving monitoring, recording and controlling a number of energy functions in different process centres of the cement plants, with the main objective of maximisation of efficiency.

In spite the fact that their conclusions are valid. They didn't indicate how to handle their recommendations. Also they didn't justify their findings, which is that the specific energy is high, and did not describe the basis that lead them to their findings.

Kokuba et al. (1983) studied the issue of improving energy saving potentials in a dry-process cement plant. They introduced two improvements in a dry-process cement plant. The first improvement targeted the clinkering process while the second targeted raw material grinding and drying process.

According to Energy Consumption Benchmark Guide (Cement Clinker Production) 2001 prepared by CIPEC, the energy among the 15 plants varies from a low of 3.68 to a high of 6.87 gigajoules per tonne of clinker. The average energy use for the 15 plants is 4.69 GJ/tonne. But the average for the four most energy-efficient plants (upper quartile) is only 4 GJ/tonne. In other words, there is a 15% difference between the most efficient mills and industry average. This significant difference suggests that many plants have ample room for energy efficiency improvements. This is an important example of the high potential for the energy efficiency improvement in the cement industry. This example, represent the industry in one of the most developed countries and it revealed that there is energy use efficiency gap between the actual situation and what can be achieved. The efficiency gap in the cement industry in developing countries is expected to be much higher, and the need for action is much more urgent.

Coppen et al. (1983) studied certain techniques for reducing electric power consumption, and subsequently cost thereof, in cement plants. They concluded that there was considerable potential for electrical energy savings by reducing system losses, but this was bound-up in a multiplicity of small individual savings. Examples are the use of high-efficiency motors in place of standard motors, the use of flat belts in place of "V" belts and the use of synthetic lubricating oils. In each case the degree of saving will be small and probably not easy to measure, but given a sufficient number of such cases the total energy saving would be worthwhile. There are, however, some exceptions where significant energy savings are likely, and these generally are where large fixed speed, damper-controlled fans are used. Here, the conversion to variable speed could be particularly advantageous. Apart from savings resulting from reduced system losses, other savings could result from the optimisation of the process quality requirements, that is ensuring that energy is not wasted on producing a higher quality product than is necessary, and by maximising the plant usage, that is ensuring that when the plant is operating it is, as far as is possible, operating to capacity.

Their above approach to locate several cases of energy efficiency improvements was by introducing some modification measures, but they didn't give attention to the causes of the energy system losses, and also did not give attention to analyse these causes as the researcher will demonstrate in the upcoming chapters.

The United Nation Industrial Development Organisation-UNIDO (1985) concluded in a study that the cement industry belongs to a group of industries, which manufacture products with high energy intensity, and in spite of that fact the industry for a long time has not paid enough attention to the problems related to the use of energy. However, only after the dramatic increase in the prices for oil in the 1970s these problems have become of primary concern for the industry since the share of the energy input exceeded 40 per cent of the production cost and energy became a major production factor. A careful look at data from developed and developing countries shows that there is a good potential to reduce specific consumption of energy in the production of Portland cement, which is the principal product of the cement industry. This indicates the existence of broad possibilities for energy saving in the cement industry, which can be realised through technological modifications, operational improvements and housekeeping measures. Since the largest percentage of the energy consumption in the production of cement goes to the process of burning the cement clinker the basic opportunities and the highest potential for energy saving relate to this part of the production chain. Prospective trends for reduction of the specific energy consumption related to the technology used in the production of cement include: calcination of clinker in a fluidised bed kiln; changing the mineralogy of cement by using mineralisers; low-temperature technology of clinker making with the use of calcium chloride; improvement of the existing grinding tube mills and application of roller mills as well as grinding aids to reduce consumption of electric power when grinding the clinker. Considerable energy saving can be realised by using secondary energy for heating purposes, drying the raw materials, generating electric power etc. Besides the possibilities mentioned above for improvement or energy utilisation of cement plants which require capital investments there also exists a considerable potential for energy saving through improved housekeeping measures at no or little cost. These include improved fuel handling and preparation, improved combustion and draft control as well as improved housekeeping in respect of electric power utilisation.

Although UNIDO study mentioned that the largest percentage of the energy consumption in the production of cement goes to the process of burning the cement clinker, it missed the fact that around 55% of the energy consumption goes to grinding the raw material and the cement clinker. The rest 45% goes to the process of burning the cement clinker, as the researcher will present in the upcoming chapters.

While the study suggested some technical measures to reduce the energy consumption, it didn't give attention to the need of introducing energy management measures as the bases of handling the problem of energy saving.

A joint World Bank/ United Nations Development Program (UNDP) study (1989) related to the issue of energy efficiency improvement in the cement sector in Syria concluded that improvements in plant operation could save considerable amounts of energy in the form of power and fuel oil. Equipment running idle and process groups operating under partial loads consume unnecessary power. Proper operation of the grinding departments is the key to acceptable power consumption levels. Unnecessary drying or over drying of raw materials is a waste of fuel oil. Quality control throughout the production process with an immediate feed back from the laboratory to the operators is a precondition for energy efficient operation. Process instrumentation and controllers and process data recording equipment have to be fully functional to permit optimum operation. A savings of 10% to 15% in energy consumption in the Syrian cement industry, which is readily feasible through the measures mentioned above, would, therefore, imply an estimated annual reduction in the country's energy consumption of at least US$ 23.5 million per year in economic terms at mid-1987 international oil prices. The main obstacles to efficient operation of the cement plants studied, which seem to be typical for the Syrian cement industry, are lack of maintenance and of well-trained and motivated plant personnel. Plant maintenance is essential for continuous operation at nominal capacity, which in turn is a precondition for optimum operation. Optimum operation is achieved by attaining energy efficiency within the limits of the given equipment and process. Preconditions for proper maintenance are good housekeeping, proper training and supervision of personnel, proper technical documentation. The managers and engineers need to spend a good part of their working time actively in the plant to exercise their leadership and supervisory function on the spot and obtain first-hand information on current operations. In order to save energy, closer supervision of operation and maintenance is needed. The nomination of an energy manager (or team) for "Total Energy Consumption Cost Analysis" (TECCA), as a part- time job, is recommended for each factory. Senior management should give full support to energy saving proposals and efforts. It is further recommended that an Energy Saving committee be formed.

While UNDP study concluded that energy efficiency improvements in the Syrian cement sector is important and valid, the study findings which estimate that a possible energy efficiency improvements of 10-15% need more analytical and supportive evidence. The study partially recommended some energy management measures to be taken like the "Total Energy Consumption Cost Analysis" (TECCA) as a part-time job for each factory. The researcher believes that as the energy cost represents around 70% of the total variable cost of the cement produced, part-time job to handle this very important issue is not good enough. However, an integrated energy management approach should be adopted and imposed to achieve the objective of the study of improving the energy efficiency in the Syrian cement sector. Another important factor was not taken into consideration is the fact that the cement sector in Syria is owned and managed totally by the government, and as a result, the industry is managed and run with limited operational efficiency and without incentives for the working force. This situation resulted in limited performance and the poor energy efficiency indicated in the study above. Furthermore, as energy prices are heavily subsidised by the Syrian government, this will be added to the reasons leading to the poor energy efficiency in the Syrian cement industry.

On the issue of the influence of variables on cement kiln performance, Makroum et al. (1995) investigated the effect of key operating variables upon the performance of the 700,000 tpy FLS precalcining kiln at the Egyptian Torah Portland Cement Co. This investigation was done using the statistical process control approach. The variables investigated included fuel division ratio (precalcinator 2/3, and kiln 1/3), kiln loading (it has an effect upon the specific fuel consumption of the kiln), and temperature distribution (over-burning has no quality benefit but it has expensive drawbacks such as excess fuel consumption). The authors concluded that the high performance of a cement kiln requires good understanding of the cause and effect model of the equipment. There is a relationship between inputs and outputs, and determination of this relationship gives a better control. Their specific conclusions were:

1) In the moderate operating range, as the precalciner / total fuel ratio increased, the overall specific fuel consumption decreased because of the bypassing effect. The bypassing effect occurs when a ratio of the kiln gas is bypassed to reduce the quantities of alkali and sulphur in the clinker, to limit the coating produced by alkali chlorine and sulphur in the raw meal and fuel, and to avoid the build up of objectionable cyclic phenomena.
2) The thermal efficiency of the kiln system is increased, as the kiln loading is increased (Makroum, 1995, p131). In spite the fact that the above study is discussing the factors that affecting the cement kilns in general and not concentrating on energy conservation issues, the above conclusion seemed to be inline with the researcher objective to establish a relation between operational variables and energy conservation.

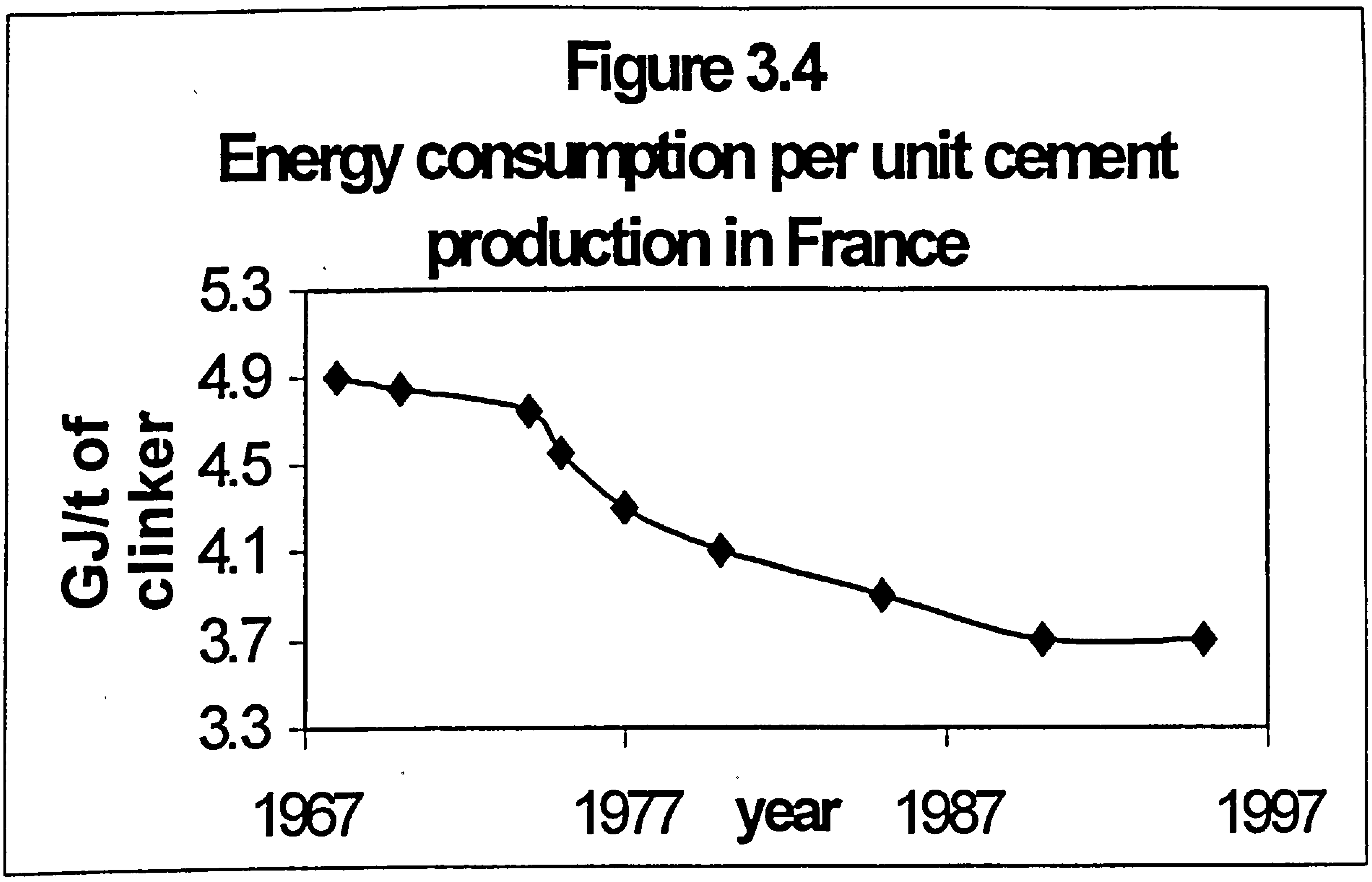
The Directorate General for Energy of the European Commission (1999) published a report analysing the energy situation in Europe. The report points out that since almost all cement plants in Europe are of the dry process type and all possible measures regarding energy conservation have already been implemented in all plants in western Europe, the improvement in energy efficiency is not expected to exceed 0.4%pa during the period 1995-2020, i.e., the total could reach about 10% in the year 2020. Moreover, this industry, in Europe, is mature; i.e. it has reached an advanced technological level related to production processes. On the other hand production of cement has been declining in the last few years. The European cement sector has witnessed an improvement in energy intensity by about 11% during the period 1990-1995. This achievement is due to a reduction in energy consumption as well as an increase in sector value added. The report concludes that this is due to the structural shift in the sector towards higher value added and low energy intensity product.

Although the report claims that all possible measures regarding energy conservation have already been implemented in all plants in western Europe, the researcher disagree with this very strong statement arguing that the report itself suggests that there is a possibility for improvement in energy efficiency that is expected not to exceed 0.4%pa during the period 1995-2020, i.e., the total could reach about 10% in the year 2020. Also the report points out that most of the energy efficiency improvements was due to mature industry from the technological point of view which convert all its cement producing kiln to the dry process and accommodate all the energy efficient technologies available. But the report didn't mention the energy inefficiency that is caused by managerial and operational aspects; those aspects represent important measures to improve energy efficiency.

In a study conducted by Worrell et al. (1995), the energy efficiency in those production processes that consume more than 1% of all primary energy in the European Union (EU) have been analysed, among them, the cement industry. The study found that energy savings could be achieved through implementation of energy management systems on the kiln, installation of a pre-calciner and recovery of waste heat, and concluded by estimating the potential for energy efficiency improvement, in percentage terms, in the cement industry in each of the EU member states and the EU as a whole. These estimates are shown in table (3.7). Large variations in the percentages among countries reflect each country's specific commitments, regulations and previous improvements.

While the above report prepared by The Directorate General for Energy of the European Commission (1999) claim that all the possible measures regarding energy conservation have already been implemented in all plants in western Europe, Worrell et al. (1995), conclude that there is a large variation on the energy efficiency improvement possibilities which vary between 0-30%. Also many cement factories in European countries can accommodate technological modification to achieve these improvements. However, he is aware of the importance of implementation of energy management systems on the kiln to achieve energy saving objectives.

Voluntary agreements have reduced fossil fuel CO_2 emissions by 25% in France between 1990 and 2000 and the CO_2 emissions per tonne of cement by 10% which will lead to improved energy efficiency. Figure 3.4 shows the historical trend in the French cement industry, where significant improvements in energy efficiency were achieved through the 1970s and 1980s. By the 1990s the energy efficiency appears to have reached a plateau of 3.7GJ/t. The specific fuel energy consumption in the German cement industry will be reduced by 20% between 1987 and 2005. (CEMBUREAU 1998). It's interesting to see that the environmental improvement measures can directly lead to improved energy efficiency, which may reflects correlated relation between the environmental and the energy efficiency issues. It's clear from the target placed for energy efficiency improvements in the European cement industry that there is still a chance for improving energy efficiency. Also the same environmental and energy conservation measures, which applied on the cement industry, may be applied on the other energy intensive industries. This will result in considerable energy saving and at the same time achieving the environmental improvement objectives.



In a report prepared by the UK Energy Efficiency Office the following energy conservation measures were recommended for the cement industry sector:

- Improved kiln insulation;
- Increased sulphate levels;
- Improved combustion control;
- Blended cements;
- Waste heat recovery;
- Improved grinding techniques;
- Low temperature cements;
- Refuse as a kiln fuel.

The report further assessed the percentage savings of each of the above measures to range from 0.3 % to 5.0 %, which is a sizeable saving for such an energy-intensive industry, as the total savings approach the value of 18% in the year 2000. Furthermore, the conversion from a wet to a dry process in some plants would add to the total savings. From this study, the researcher concludes that there is substantial room for energy efficiency improvements in the British cement industry. This study concentrated on some technical measures and modifications to improve the energy efficiency and resulted in some improvement figures, which is very generalized, and need supportive analysis and evidence. Also it ignored the energy management issues as a very important energy conservation measures.

The difference among the expected savings potential of the various studies can be explained as follows: While the EC study estimates the savings throughout the period 1995-2020, the other two studies pertain to savings for the year 2000. Moreover, the Energy Efficiency Office study pertains to the U.K. alone while the other two studies consider all countries of the European Community, in addition to the different interpretation by the reports and study's authors.

Table (3.7)

Estimated Potential for Energy Efficiency Improvement in Cement Industry (%)

Country	**Belgium**	**Denmark**	**France**	**Germany**	**Ireland**
(%)	25	30	19	0	1

Country	**Luxembourg**	**Netherlands**	**Portugal**	**Spain**	**UK**	**EU**
(%)	1	30	0	10	**21**	**13**

Another measure of energy conservation is the use of waste as an alternative fuel in the cement industry in order to reduce the use of non-renewable fossil fuels such as coal as well as the environmental impacts associated with coal mining. It also reduces the emissions of greenhouse gasses by replacing the use of fossil fuels with materials that would otherwise have to be incinerated with corresponding emissions and final residues.

The use of alternative fuels in cement maximises the recovery of energy from waste; it is a safe way of valorising waste. The organic constituents are completely destroyed due to the high temperatures, long residence time and oxidising conditions in a cement kiln. (CEMBUREAU, 1997). Blue Circle, which has only used 3% alternative fuels, has recently signed a joint venture with Michelin to use half of the tyres scrapped in the UK each year, leading to annual savings of £6M. (IPPC S3.01, 2001).

Based on the previous review, it can be concluded that technical measures can be employed to a great effect within the cement industry, as the examples here illustrate. Studies in a number of countries and regions have concluded that technical progress has been made and can still be made, and we can take the reported figures as guides to suggest the best energy efficiency benchmarks. Since the reports have been prepared in different ways, an exact interpretation of each and a comparison between them must be dealt with great care to avoid any serious misinterpretation.

3.7.2 Fiscal Instruments applied to Energy in the Cement Industry

At the Kyoto Summit in 1997 a World reduction in greenhouse gas emissions of 5.2% below the 1990 base line was to be achieved by 2008-2012. The European Union committed to an 8% reduction, and the United Kingdom's share of this represented a national reduction of 12.5%. The UK Government of the time declared a more stringent target of 20% by 2010.

To help to meet this target, by discouraging the use of fossil fuels, the UK Government introduced a new tax - the Climate Change Levy or CCL, which will increase businesses' energy costs by 10 to 20%. A compensation for this is a 2.5% reduction in the employer's contribution to National Insurance.

As of April 2001 the tax is;

Coal £0.0015/kWh, Gas £0.0015/kWh, Electricity £0.0043/kWh

Liquid Petroleum Gas £0.0007/kWh (source IEMA, 2001)

For the UK cement industry, in common with other high energy consuming industries and companies, there is possible relief from this tax. The Government has recognised the burden that the tax would impose on energy intensive industries that would not necessarily benefit from the National Insurance reduction because they have relatively few employees. Climate Change Agreements, CCA, are negotiated either individually or by a whole industry. To qualify for the CCA the industry has to be within the framework of Integrated Pollution Prevention and Control, IPPC, and has to have established agreed energy or carbon reduction targets. Carbon reduction in the cement industry specifically important because according to Ernst Worrell et al (2001), in 1997 industrial energy use and process emissions from the cement manufacture accounted for 33% of the total US CO_2 emissions (which is substantial figure, and this is due to the calcinations of the limestone for the production of clinker, where 44% of the total weight of the limestone is converted to CO_2) i.e. process CO_2 emissions from calcinations are added to the cement sub sector energy related CO_2 emissions.

Integrated Pollution Prevention and Control is a regulatory system that employs an integrated approach to control the environmental impacts of certain industrial activities. It involves determining the appropriate controls for industry to protect the environment through a single Permitting process. To gain a Permit, Operators have to show that they have systematically developed proposals to implement the 'Best Available Techniques' (BAT) and to meet certain other requirements, taking account of relevant local factors. IPPC for the cement industry is addressed in detail in IPPC S3.01 (2001). IPPC operates under the Pollution Prevention and Control Regulations, which were enacted in England, Wales and Scotland in 2000 to implement the European Commission

Directive 96/61 on IPPC. The essence of BAT is that the selection of techniques to protect the environment should achieve an appropriate balance between realising environmental benefits and the costs incurred by Operators. (CEMBUREAU, 1999)

The implementation of the framework of Integrated Pollution Prevention and Control, IPPC, and the adoption of the 'Best Available Techniques' (BAT) in the industry will achieve the environmental objectives, which will certainly result in improving energy usage efficiency, and can be considered as instrumental and effective energy conservation measures.

The British Cement Association has agreed to cut carbon emissions by 25.6% from a 1990 base line by 2010 in exchange for an 80% reduction in CCL. Intermediate targets for energy consumption as presented in table (3.8), have to be met by the ends of calendar years 2004,2006 and 2008. (DETR, 2001). Other UK energy intensive industries have agreed reduction targets: the only ones with more stringent targets than cement are: Paper and Board (40%) and Aluminium (32.2%). The Chemical industry is next with a target of 18.3% over the same period (IEMA, 2001)

Table 3.8

Climate Change Agreement Targets for the British Cement Industry

End of year	kWh/kg cement	GJ/tonne cement
2002	1.457	5.245
2004	1.408	5.069
2006	1.298	4.673
2008	1.282	4.615
2010	1.249	4.496

The UK Government has also introduced enhanced capital allowances (ECA) to encourage industry to purchase certain types of energy-efficient technology with full capital depreciation allowed against tax in a single year.

Guidance on the environmental effects of the cement industry in Arab countries is provided in AUCBM (1998)

It can be concluded from the previous review that fiscal measures are being introduced by certain countries to pressurise their cement industry towards reducing their emissions of climate change gasses. In particular the UK situation is cited here since a Climate Change Levy was added to commercial energy bills in April 2001. The UK cement industry has entered a voluntary agreement to make annual improvements in energy efficiency in return for relief from the full levy. The CCL is applied at a lower rate. According to this agreement the UK cement industry should produce cement using 4.496 GJ/tonne by 2010.

3.7.3 Previous investigation of using statistical techniques and analysis in cement industry and other highly energy intensive industries

A survey of the largest cement manufacturers like (Holderbank and Lafarge), the regional cement associations like (British Cement Association, Arab Cement Union, Cement Bureau),and the professional bodies like (Institute Of Chemical Engineering and American Institute Of Chemical Engineers) revealed little evidence of any previous usage of statistical techniques. Likewise internet searches, even though they sometimes contained case studies /profiles/guidelines and papers related to the subject actually resulted in little evidence of statistical techniques. A specialist information officer from the Institute of Chemical Engineers was contacted and asked to search for the required statistical analysis in several highly intensive industries. Most of the contacted parties apologised or supplied papers which were irrelevant.

The results of the survey were as follows:

First: Holderbank data

Statistical data from Holderbank was obtained and was found to contain many of the important parameters and variables recorded for over 50 production lines including kilns and cement and raw mills. These variables can be used effectively for a useful statistical analysis but Holderbank reported that they are neither performing these analyses nor implementing a detailed energy management system.

Second: Whitehopleman benchmarking

There is a new initiative, introduced in 1998, called the Whitehopleman-International cement review benchmarking service. This service has grown, with data from more than 150 factories and 200 kilns all over the world. This service gives confidential benchmarking between these factories for more than 50 performance indicators focusing on: Safety, productivity, energy efficiency, reliability, environment emission and quality. According to the findings in the year 2000, it is clear that cement companies large or small are struggling to operate kiln in long uninterrupted campaigns of reliable performance. The findings of this initiative were that there is a major need for the industry to improve performance. Measuring current performance allows the gap to achieve best performance to be quantified and realistic improvement targets to be set. Also it will leads to identify the steps necessary to close this gap. Many roots to improve performance are available, but the key contributor is detailed knowledge of practices of the best performing companies. In accordance to these initiatives and according to Michael Clark (2000), it appears that many cement companies maintain records of the underlying reasons for kiln stoppages, these are classified into the categories of mechanical, electrical and process or operational related features. Efforts then can be directed to eliminating these common causes of kiln stops. This bench marking service is moving in the right direction by collecting all the relevant information and statistical data which can be used in the future to build an effective statistical model which may be similar to the one this research is aiming to conclude.

Third: US Department of Energy

Through our search of other highly intensive industries it has been found that there is a real interest of the issue of energy management and conservation and it was noticed that the effort concentrated on a specific energy saving item and not on establishing an integrated energy management system. For example, according to Energy Information Adminstration of US Department of Energy, the Industry Analysis Brief (2000) showed that about 61% of the steel industry population reported engaging in at least one energy management activity. This shows the relative importance of energy as an input in the manufacturing in terms of its cost as a percentage of total production cost. If these reporting industries consumes nearly 94% of the total steel industry energy, then one concludes that energy management is a major concern for the whole steel industry in the U.S.A. This fact is appreciated even more if one knows that energy costs accounts for about 15% of the manufacturing cost of steel.

As for the chemical industry the interest in energy management is less than the steel industry. About 36% of the chemical industry reported engaging in at least one energy management activity. On the other hand about 68% aluminium industry reported engaging in at least one activity of energy management.

These examples show that although the awareness of the importance of energy management in intensive industry is high, there is still room for more action in this direction. It is noticed that the energy management activity referred to engaged in one activity or more, this indicates that the approach is not a complementary integrated approach working within an energy management system which can achieve complementary results for the whole system but is only isolated and separated activities, which can not achieve the desired objectives. Naturally, the above discussion pertains to the U.S.A but similar conclusion applies to the rest of the world, regarding the potential of energy saving for energy intensive industries by using energy management techniques.

After this exhaustive long search to survey a possible previous use of statistical analysis especially the analysis of the effect of the variables on the energy consumption such as loading rate, availability, duration and number of stoppages etc which was carried out by the researcher through contacting several specialized parties (a list of these parties is attached in the appendix no. 22). The out come of this search shows that although ample evidence of the interest of cement and other energy intensive industries in energy management, there is no such a statistical analysis of the variables affecting the energy consumption.

All these search and findings and the material received or downloaded were not very relevant to our research subject.

Fourth: Other contacted parties

In the following a summary of the received answers of the contacted parties concerning our research:

1. The Washington State University Energy Program

   David Shepherd informed us to download any publication from their site or department of energy site. The material found in both sites was irrelevant to our research.

2. American Institute of Chemical Engineers

Debbie Beaudreau informed us that they did not have such an information and suggested visiting National Science Foundation website. That site was referred to without finding useful information.

3. UK Department of Environment, Transport and the Regions

After contacting several bodies the author was guided to the Energy Efficiency Best Practice program (EEBPP), which aims to advance and spread good practice in energy efficiency by providing independent authoritative advice and information on good energy efficiency practices. Best practice is collaborative program targeted towards energy users and decision makers in industry, the commercial and public sector and building sectors including housing. The help line guide in this program guided us to useful publications in energy management field but not very relevant to our research topics related to statistical analysis of the factors affecting the energy consumption.

4. Natural Resources of Canada

The contacted person was Mr. Philip B. Jago (Chief, Industrial Energy Efficiency Initiative. He supplied us with very interesting information which shows a serious organised effort to improve the efficiency of the energy used. Natural Resources Canada "Canadian Industry Program for Energy Conservation" (CIPEC) seeks to promote energy conservation in industry as way to improve the competitiveness of Canadian industry locally and internationally. This involves monitoring industry's progress in energy efficiency. Historically, CIPEC collected information on industry energy consumption through its own process of data collection. CIPEC now depends on existing data collection agencies and the activities of Canadian Industry Energy End-use Data and Analysis Centre (CIEEDAC) to provide data on changes in energy consumption and energy intensity in various industries. In one of their documents they reported on (Energy Consumption, Production and the Indicators) the following:

Production in Canada's cement industry increased by only 4% in 1999 over 1998,even though energy consumption increased significantly. Physical energy intensity followed a generally declining trend from 1990 to 1997 but has increased over the past two years. In 1999 physical energy intensity was 3.8% lower than 1990. This is a very clear evidence of the great achievements they manage to materialise through their ambitious well-managed efficiency program. John Nyboer(2001).

In another document issued by CIPEC under the title (Energy consumption bench mark guide: Cement, clinker production), they reported that the Canadian cement industry has long recognised that the cost of energy can be significant varying between 25% and 35% of the variable direct cost consequently, the industry is continuously investigating and adopting more energy efficient technology to improve its profitability and competitiveness. In particular plants have moved steadily from less energy – efficient wet process kilns towards the more fuel – efficient dry process kiln. The industry has achieved additional energy efficiency gain by using preheaters and precalsiners. These technologies have helped the industries reduce its energy consumption per ton of cement by 30% since the mid – 1970s. Also it reported that energy use per ton of clinker decreased by 14% over the nine year period between 1990 and 1998 reflecting continued technology improvement including converting from wet process to dry process, preheater / precalsiners addition new installations and retrofits to increase average kiln capacity and continuous improvement in general operating practices. In the same report it is stated that there is 15% difference between the average energy use of the most efficient production lines and the industry average. This significant difference suggests that many plants have ample room for energy efficiency improvement. CIPEC 2001.

CIPEC in its mission to promote voluntary action that reduces industrial energy use per unit of production reported that they managed to achieve an overall annual average improvements in energy intensity from 1990 base year through 1998 is 1.26% per year exceeding their target of 1% per year. CIPEC annual report 1999.

In the same report they reported some success stories as follows:

- Aluminium industry: The industry is actively perusing technological advanced that promise enhanced energy efficiency from 1990 to 1998 the sector increased but 51% while reducing the emissions per unit of production by 41%, this indicates huge energy savings achievements.
- Fertiliser industry: The sector continue to develop energy efficient technology, they reported that energy consumption by Potash producers has risen but the energy component per tonne has declined from 3.92 GJ per tonne in 1990 to 3.72 GJ per tonne of output in 1998. Overall energy indicators show an improvement in energy intensity that averages more than 1% per year since 1990.
- Steal industry: Canadian steel makers continue to emphasise energy efficiency as a major thrust of productivity, quality and cost reduction efforts. Since 1990 the industry has achieved a 15% improvement consumed per tonne shipped, the average annual energy improvement was 1.9%, surpassing the industries commitment of 1% per year from the adjusted rate of 1990. This was achieved through modernising their industrial processes with substantial capital investments and improving their energy management practices.
- Pulp and paper sector: Companies continue to improve energy intensity and implement programs to switch from fossil fuels to biomass. Fuel switching

along with better use of existing equipment, adopting of energy-efficient equipment and processes and increase use of cogenerations have enabled the industry to meet its energy efficiency goals. They managed to improve its energy consumption per tonne of output by 10.5% since 1990. This achievement is consistent with the industry's commitment of 1% improvement in energy efficiency per year from 1990 to 2000.

5. UK department of trade and industry

The contacted person was Zaman Shopna, who referred us to some publications "Digest of UK Energy Statistics 2000" and "Energy Paper 66, Energy consumption in the UK". These documents containing useful statistical data but irrelevant to our research topics.

6. Institution of Chemical Engineers (IChemE)

The contacted person was Teresa Farthing. She referred us to the institute of energy UK but the information available is very general. She was asked to do a literature search on our thesis. The search topic including the titles which are based on the energy side of our query which was concentrating on energy efficiency issues and the variables factors affecting its consumption etc in those industries including some of the energy intensive industries including cement, glass, iron, steel, concrete and ceramics combining the search with a sets of keywords associated with failure rates, stoppages etc. The result was a list of 77 papers and literatures which were after studying its abstracts found to be irrelevant to our research topics.

She repeated the search to find any documents dealing with establishing a statistical relation between energy consumption (fuel and electricity) and some operational variables like production rate, availability, production rate, stoppages (duration and no). In this search the key search words used were :

- failure rate/no of stoppages/no of breakdowns
- duration of stoppages/stoppages time
- availability
- production rate/loading rate
- statistical analysis and energy management systems

The search again concentrate on energy consumption issues in energy intensive industries like cement, glass, iron steel etc. After this detailed exhaustive search, she reported that she did not find any relevant titles related to our research topics.

7. British Cement Association

The researcher contacted the British Cement Association, they perform a search for the above mentioned topics related to his research and he received a list of the available literatures in their library. He selected some of these literatures which may be related to the subject, he received the materials and unfortunately nothing was relevant to our main topics.

One of the important documents received was prepared by FLS, one of the biggest manufacturers of cement equipment, and it was concentrating on the method of improving energy efficiency in the cement manufacturing process.

It concentrates on the possibilities in saving energy on grinding of raw material by introducing the roller press technique. Experience proven that this process may save a considerable amount of energy in comparison with grinding unconventional vertical or ball mills.

Also it concentrates on energy saving in kilns, they estimate that 5% reduction in lime saturation factor can reduce the fuel consumption by 10-20 Kcal per kg of clinker. Also they reported by adding a fifth cyclone stage to a 4-stage preheater it is possible to save 25 kcal per kg of clinker. They suggested to improve the insulation of the preheater, precalsiners and the kiln.

For the cement grinding they recommended to use small grinding media and to equip the ball mills with high efficiency separator, as compared with the traditional separator it would give a reduction in the specific energy consumption of about 25%.

8. CEMBUREAU: European Cement Association

CEMBUREAU was contacted for the same purpose and it was found that according to their site that the available information was related to annual statistical data of the production of European cement factories. Some important documents found were world cement directory, cement standards of the world, world statistical review, and European annual review. World statistical review (annual) covers practically all countries of the world and contains data on cement production, imports, exports and consumption for the last three years.

The available data were very useful for the cement manufacture all over the world but it is irrelevant to our research subject.

9. Arab Cement Union (AUCBM)

The AUCBM aims principally at developing and supporting technical, industrial and commercial relations; coordinating industrial activities amongst its members (Arab cement and building materials companies all over the Arab world) in the field of cement and building materials; and participating in suggesting general grounds for developing these industries in Arab countries. The reseacher search the documents available and found out that it concentrated on technical and statistical issues. The researcher met the secretary general of the union who explained that there is proper awareness of the importance of the energy usage efficiency in cement industries, but still a lot can be done to improve the energy usage efficiency and until now statistical analysis for the factors affecting the energy consumption are not applied, and such a scientifically efforts needs cooperation between the scientific centres like universities and research bodies which hopefully can be encouraged in the future.

It can be concluded that despite a comprehensive survey of the cement and other energy intensive industries, it has been impossible to find a statistical approach to the problem. Several reports gave detailed information which could have been used to develop a statistical model, but as far as is possible it must be concluded that so far this has not been applied to the cement industry and other energy intensive industries. The work in this thesis, is therefore represents the first attempt at employing such an approach to the cement industry.

3.7.4 Previous Investigations of Energy Management

Fawkes (1985) examined the potential for conservation investment and possible savings in the brewing, malting, distilling and dairy industries. The main objectives of his research were: assessing the extent of energy conservation activity and techniques used in the above mentioned industries; assessing the potential for further energy conservation; and examining barriers to further change. In achieving the first objective, Fawkes looked at the level of specific energy (energy per unit product) reduction and the techniques used in the four sectors studied for conserving energy, and analysed the characteristics of energy management systems. Fawkes did not give sufficient attention to the factors and causes of high specific energy consumption, which are believed to be fundamental to achieving his first objective. As for the second objective, he built a model to analyse the general technical change in order to define potential for further change. The model also allowed the author to describe the activities necessary in energy management. Whilst this was a useful model, it was proposing a partial approach, which did not integrate the component parts into a comprehensive management system. Finally, to achieve the third objective of his thesis, Fawkes used the model of technical change mentioned above to examine the barriers to further change. He divided the barriers into techno-economic and management. Having said that, caution must be exercised when studying whole industrial sectors rather than a single industrial enterprise. In the latter case all the issues related specifically to a particular plant are taken into consideration and all analysis is at the " micro" rather than the "macro" level. This permits a strong understanding of causal relations and thus facilitates directed actions to improve energy performance.

Fawkes and Jacques (1987) published a paper related to the above-mentioned thesis. In this paper, the authors reported the detailed management methods used in breweries, distilleries, malting and dairies and their relative effectiveness in achieving significant energy savings. These conclusions were based on a survey in which companies were classified by three levels of production scale, and according to six types of management characteristics related to the extent of monitoring, targeting and cost-centre reporting procedures that were in use. In addition, two cases were cited which illustrated the benefits of questioning and measuring energy cost centre activities and at the same time provided a logical explanation why, in some cases, equipment investments do not produce major returns, while others can produce major results. The paper concluded that an optimal energy management information approach is very important in promoting housekeeping, constructive retrofit investment and therefore significant energy cost reduction. The analysis made in the paper was useful but it ignored human attitudes towards energy information management, which could differ from one manager to another. Some managers may view the frequency of reporting and other management issues differently from others, depending on their background and culture. Attention should have been given to management paradigms, particularly to how they can be changed, where appropriate, in order to improve the efficiency of energy use.

A study conducted by a group of European consulting firms (Cowi Consult, 1993) within the framework of the THERMIE program concluded and recommended that energy control and management systems be among the priority issues for the cement sector in the nineties.

The issue of energy conservation started to be very popular in industrialized countries immediately after the first oil shock of 1973. Therefore, a shift in energy policy of these countries has occurred to reflect the importance of energy conservation to the survival of these economies. In addition, Research and Development (R & D) efforts have intensified to come up with alternative, more efficient, technologies, which would use less energy per unit of output.

Ross (1989) analysed the recent history of energy use by manufacturers and discussed future energy use, especially in terms of technical change in electricity use. His paper emphasized that a critical element in understanding trends in energy use is that the manufacturing of bulk materials, including pulp and paper, industrial chemicals, petroleum refinery products, glass and cement (not including fabrication), is roughly ten times as energy intensive as the rest of manufacturing. However, he pointed out that the consumption of products whose manufacture is energy intensive is in relative decline in advanced industrial countries like the United States. He then raised the question, how much of the real efficiency improvement opportunity was exhausted during the late 70s and early 80s when society focused its attention on energy and a great deal of energy efficiency improvement was achieved? Ross claimed that the cost-effective opportunity now available is larger than the savings so far achieved:

"Specific technologies provide one kind of evidence for this claim:

- Energy management systems that control equipment and lighting in non-production hours have been applied in quite a few plants, however, most plants do not have sophisticated systems.

- Electronic motor controls are still relatively rare, so that new applications continue to be described in "technical literature" (Ross, 1989, p 13).

Finally, Ross argued that the future pace of improvement in end-use efficiency and in the pace of electrification is not well understood. Therefore, he presented a systematic discussion of the different areas of new technology and their potential effect on the real electricity intensity in terms of representative examples. To illustrate his point he only addressed sensing and control, whereas the main role of some controls is to increase product yield for a given input of materials. Energy and other inputs per unit of production are thus decreased.

The researcher tends to agree with the main findings of Ross in which he claimed that the cost-effective opportunity now available is larger than the savings so far achieved. The previous literature review in which many authors claim that energy efficiency improvements opportunities still exist and can be varied between 0 and 30% also support Ross claim, it also confirms the need and the importance of the research subject.

Energy Management has been investigated in a number of industries, as several authors report. Some of their work provides valuable insight into the topic, including issues such as the decline of energy intensive manufacturing in favour of less energy demanding industries.

3.8 Conclusions

Cement manufacture is highly energy intensive and several important issues surrounding Jordan's cement industry: the consumption and cost of raw materials, water and energy, the greenhouse gas emissions and security of energy supply. The economical, management, technical and financial aspects of energy efficiency have been examined in this chapter as a basis for the development of the research model.

In this chapter, definitions of key energy-related concepts, including energy conservation and the efficiency of energy use, have been given. Furthermore, a general overview of the energy sector in Jordan has been presented with particular emphasis on the relationship of energy and economy, primary energy consumption and electricity consumption by sector. Although the development of energy and electricity intensities in Jordan has been shown, no actual trend is obvious.

Comparison of energy intensity in Jordan with the energy intensities in several world countries was made. As for energy intensity, Jordan's figure is more than double the figures of the USA or UK. This comparison shows that the potential for energy conservation in Jordan is high.

This chapter included brief information on the principles of energy conservation, the Jordanian Government's measures for the promotion of rational use of energy, the obstacles to energy conservation in Jordan, and a summary of the energy conservation studies conducted for the industrial sector in Jordan.

Finally, a detailed review of related previous research and literature was presented in this chapter, including; Technical Measures relating to Energy, Fiscal Instruments applied to Energy, and Previous investigations of using statistical techniques and energy management systems, in the cement and other highly energy intensive industries.

It revealed from the literature review that there is a 15% difference between the most efficient mills and industry average in the some of the developed countries. This significant difference suggests that many plants have ample room for energy efficiency improvements. This is an important example of the high potential for the energy efficiency improvement in the cement industry. Also it revealed from this literature review that there is an energy use efficiency gap between the actual energy efficiency and what can be achieved. The efficiency gap in the cement industry in developing countries is expected to be much higher, and the need for action is much more urgent.

Based on this review, it can be concluded that technical measures can be employed to a great effect within the cement industry, as the examples here illustrate. Studies in a number of countries and regions have concluded that technical progress has been made and can still be made, and the reported figures can be used as guides to suggest the best energy efficiency benchmarks.

Fiscal measures are being introduced by certain countries to pressurise their cement industry towards reducing their emissions of climate change gasses. International cement manufactures are coming under increased legislative pressure, in particular the UK situation is cited here since a Climate Change Levy was added to commercial energy bills in April 2001. The UK cement industry has entered a voluntary agreement to make annual improvements in energy efficiency in return for relief from the full levy. The cement industry is aware of its responsibility and obliged to adopt good environmental practice, which indeed incorporates good energy management practice. This emphasises the real need for the main theme of this thesis.

In a simplistic way the amount of energy saved (or not consumed or burned) means a corresponding amount of gas emissions not emitted to the atmosphere. This is why the Kyoto Protocol called for 38 industrial listed countries to reduce their emissions of greenhouse gases by an average of at least 5% below their 1990 level by the year 2012.

Despite a comprehensive survey of the cement and other energy intensive industries it has been impossible to find a statistical approach to the problem. Several reports gave detailed information which could have been used to develop a statistical model, but as far as is possible the conclusion must be that so far this has not been applied to the cement industry and other energy intensive industries. The work in this thesis therefore expected to represent the first attempt at employing such an approach to the cement industry. To be more specific, through the review the author could not identify any existing detailed empirical and analytical approach for the main factors affecting the energy consumption in the energy intensive industries. Also, no significant attempt to develop a statistical model using these factors for the cement or other highly energy intensive industry could be found. Further, we have been unable to locate a detailed integrated energy management system, which has been developed or used.

Energy Management has been investigated in a number of industries, as several authors report. Some of their work provides valuable insight into the topic, including issues such as the decline of energy intensive manufacturing in favour of less energy demanding industries.

In summary the review confirmed the importance of investigating the research problem as it revealed that it exists at a global level and its economical and environmental implications is of great importance.

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Chapter Four

Methodology of Research

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Chapter Four

Methodology of Research

4.1 Introduction

The present research is addressing the problem of improving energy usage through the application of effective management techniques aimed at reducing energy consumption per unit cement produced. This research undertakes a comprehensive analysis of energy usage patterns, the factors affecting them, and the cost implications. The results of this research will be very useful and applicable to other industries in the country as well as in other parts of the world.

The foregoing chapters have presented the background to the present research, in terms of the importance of energy and its rational use, in addition to a review of the related previous research and literature.

This chapter defines the methodology adopted to achieve the study objectives. A detailed description is given of the research steps and its approach for energy management and energy saving in the Jordan Cement Company.

The methodology of the research blends theoretical work with practical evidence. In other words, the methodology includes production-costing, analysis of the factors affecting energy consumption, statistical and economic models in addition to certain case studies of energy conservation. Moreover, the thesis also includes a description of an energy management system including organisational structure and job descriptions. This blend of theory and practice provides convincing evidence of the workability of the models derived and the ideas and concepts promoted.

4.2 Steps of Research

The research involves the following steps:

1st Literature review of industrial energy management and conservation issues and practices, with particular reference to the cement industry, in order to introduce the main areas of interest in this research. This step helps in identifying efforts previously done by others in the areas of interest in the research. This includes previous research, professional papers in seminars or conferences, consultants' reports, industrial norms and standards, trade associations, and regional and international organisations publications, etc.

2nd The production cost of cement is affected by several elements, which include: type of process used, energy, availability of raw materials and the management system adopted by the company. Since the cement industry is considered an energy intensive industry, then the most important cost element is that of energy. The analysis of production costing is used in the justification of the research work. It is hoped to show that electricity and fuel costs constitute a sizable portion of variable cost of the production of cement. Therefore, it is worthwhile to attempt to reduce these costs by reducing consumption of fuel and electricity. This is achieved through utilising the relationships among fuel and electricity consumption and other operational variables as shown in the statistical model, which is tested via the economic model.

3rd Statistical analysis of factors affecting the consumption of energy in the cement industry in order to develop the necessary mathematical functions relating energy consumption to the defined significant factors, which help to demonstrate, mathematically, the significance of energy management to production factors. The statistical model uses historical data for certain independent variables and the desired dependent variables; namely electricity and fuel consumption. The outcome of this statistical analysis is a model, which may be used, to a certain degree of confidence, to describe the relationship between each of the two dependent variables (electricity and fuel consumption) and the independent variables.

4th Transforming the statistical model into an economic model, which relates cost of energy consumption as a function of the cost of improving the independent variables affecting energy consumption. The objective of building the economic model is to verity whether there will be financial gains from reducing energy (fuel and electricity) consumption as predicted by the statistical model or not. Furthermore, the size of such gains can assessed using the economic model and the results compared to the weights of energy consumption with respect to production costs.

5th Development of an Energy Management System (EMS) to reduce energy consumption while maximising the throughput of the industry. This system includes an organisational structure, job descriptions and work instructions for activities related to energy management. It also touches on the relationship between energy management and total quality management. In other words, it integrates the energy management system with the operational strategy of the cement plants.

6th Measurement of savings in energy consumption, through analysis of several cases studies. These case studies represent certain measures undertaken to verify the possibilities of energy saving options available in cement industry. Most of these measures have been tried elsewhere, but there is a need to check whether the particulars of the local cement plant would change the outcome. Therefore, these case studies serve as witness to the possibilities of savings as a result of energy management measures.

4.3 Description of Approach

The approach adopted for the research is presented in detail below. It is important to note that the elements of the approach are directly linked to the steps of the research in much the same way as the latter are related to the objectives of the research. However, there is no one-to-one direct correspondence, i.e., items in the approach may relate to one or more items in either the steps or objectives of research.

4.3.1 Energy Costing in Cement Manufacturing

Cost monitoring and control are two important attributes for business success. As such, management accounting has become one essential element of the overall business management activity and has received wide attention and research. However, some business managers still fail to see the importance of applying new management accounting techniques, especially to new manufacturing technologies. According to Tayles and Drury (1994), during the 1980s, European manufacturing companies faced significant and radical changes in both manufacturing technologies and the level and nature of competition. They refer to criticisms that management accounting has hindered rather than helped these changes to come about, in that it has failed to make visible, and therefore governable, the detailed work processes of a modern manufacturing organisation.

Tayles and Drury conclude from their research work, which involved a survey of practising managers of UK manufacturing companies, that management accountants have an important role in helping to make the detailed work process of companies transparent and subject to control. Accountants must become involved with executives of other disciplines in cost control and product costing at the planning and product design stage. The authors suggest that this will enable accountants to participate more fully in the provision of relevant, financial and nonfinancial information, to appraise investment in advanced manufacturing technologies and to cost and control the products and processes involved.

This research studies and analyses the cost of energy used for cement manufacturing and its share of the total cost of cement production in Jordan for the period 1985-1992.

Detailed energy costing is a viable monitoring tool since it helps management detect abnormalities, and therefore, take necessary measures to eliminate the causes and effects of these abnormalities. Moreover, energy costing is a useful accounting tool to help management control the financial flows of a company, especially when energy cost is a high percentage of total production cost. Consequently, this activity leads to improvement in the budgetary control of production and other functions of the company.

Moreover, energy costing allows management to keep records of energy costs for each production process or sub-process, and to relate such costs to production quantities. This, in essence, is a productivity tool, in addition to its use for energy cost control. It will undoubtedly lead to improvement of productivity (maximisation of benefits) as well as prioritisation of investment allocations for different aspects of manufacturing, including those related to the improvement of the efficiency of energy use.

Although energy costing as a tool has previously been used at the Jordan Cement Factories (JCF), it should be built into the system of manufacturing because of the above-mentioned advantages.

4.3.2 Practical Energy Saving Exercises

According to Dr Khatib the ex – minister of energy in Jordan during a meeting to discuss the energy conservation issues, the main barrier to industrial efficiency in Jordan's small and medium-size industrial sector appears to be the lack of awareness of the benefits of energy conservation on the part of industrial plant mangers, and the limited access to, and knowledge of, energy efficient equipment. In order to overcome this barrier, a major outreach information and training activity is required, to include both potential "users" of energy conservation equipment and techniques, and potential "suppliers" of energy conservation equipment and services.

Jordan Cement Factories (JCF), a few years ago, were no different than the average industrial enterprise described earlier. Probably the lack of awareness concerning energy management was caused by the concentration on production to meet a phenomenal demand, although, this is not an excuse, as energy is a very important input in cement production. Gradually, attempts were initiated to address energy conservation issues in no particular plan or order. Over time, several successes have been achieved.

Need, has often been referred to as the "mother of invention or innovation," and this is relevant to our case. The experience of JCF in energy conservation (saving), as a set of case studies, is used to prove the need for more concentrated and organised effort in energy management, specifically, the need to institutionalise the functions and activities of the Energy Management System (EMS). It is worth noting that case studies help in proving (or disproving) that certain energy management measures or tools work even under the conditions and specific situations of the local cement industry. Therefore, case studies work as yard sticks to measure and verify the applicability of energy management tools.

Each case should show that potential energy saving opportunities exist at JCF, and although the measures described were isolated and conducted in a non-systematic manner, most of them were cost effective. Therefore, if all such efforts were integrated within an institutionally recognised Energy Management System (EMS), it is expected that even more profitable results would be achieved.

4.3. Statistical and Economic Models

The statistical analysis is very useful for monitoring and controlling cement production processes and optimising their output. It is also useful in studying the effects of production stoppages on the overall productivity of the manufacturing system.

In this research, the relationships among electrical consumption and fuel consumption as dependent variables and number of stoppages, duration of these stoppages, production rate and availability and other independent variables are studied using statistical analysis technique. These statistical techniques come as a tool to investigate the relationship among dependent variables and independent variables. The objective of this research is to demonstrate this relationship using several statistical models depending on regression analysis. The regression analysis is used to search the independent variables that explain a significant amount of variation in the dependent variable. Several types of regression procedures, such as multiple linear and non-linear regression, stepwise regression, ridge regression and robust regression analysis will be used as statistical tools to determine the presence and significance of potential relation relationships among the variables of the studded area.

The analysis of these relationships is helpful in studying the factors, which influence the levels of electricity and fuel consumption in cement plants in Jordan. The outcome is expected to reveal the degree of inter dependence between both dependent and independent variables. This should help the management focus on variables that are highly affecting the energy consumption and hence, control them in a much more efficient manner.

The statistical analysis carried out within this research work had never been carried out at JCF before. As a matter of fact, this research work is original in the sense that no other research work attempted to formulate a statistical model for the energy consumption for cement industry before. To the extent of our exhaustive search, we could not trace the use of such statistical analysis in the international cement industries and the other energy intensive industries. The methodology thus established could be used by others to study and investigate relationships between other dependent and independent variables. Moreover, the results of the statistical analysis are expected to be useful for the research work, as causes and conditions of excess energy use are identified.

The statistical model is complemented by an economic model. The economic model will attempt to calculate the cost of energy consumption through the use of the cost of each of the independent variables. Since the statistical model will relate electricity and fuel consumption with the other independent variables, then the economic model will translate these relationships into monetary terms. In other words it could be used to predict the value of savings in electricity and fuel consumption, which would result from reducing consumption if the independent variables are improved or controlled. However, this economic model will need further testing using more recent data and estimates of the cost of changes effected on each of the independent variables, which is beyond the scope of this research. Nevertheless, the model will be theoretically tested using "would be" values for electricity and energy costs, which would result from improving availability and production rate and reducing number and duration of stoppages.

4.3.4 Effect of Management Procedures on Energy

Mosekilde et al (1982) studied the dynamics of business decision- making of manufacturing companies with regard to energy management. In their work, the researchers investigated the following:

"(i) how long a time will it take the industry to renew its production capital and achieve an energy efficiency corresponding to today's fuel process; (ii) how much better can this energy efficiency be expected to be; and (iii) how much can be done in the meantime to reduce energy consumption through retrofitting and improved usage of existing capital."

Energy conservation is a company-wide activity involving almost all aspects of production and support services. It also requires decisions that cut across the hierarchy of the company and require financial and human resources for implementation. In short, energy consumption/conservation is a management activity and should be labelled as energy management.

Management practices and procedures affect the level of energy consumption in a manufacturing firm. Moreover, they also affect the degree of application of energy conservation measures, which would improve the efficiency of energy use. For instance, if the top management of a firm is committed to the enhancement of the productivity levels and it appreciates the benefits of energy management to the improvement of productivity, then things will move in the right direction. The commitment of top management is translated into making energy a top priority; monitoring energy consumption patterns for different parts of manufacturing processes is therefore essential. Moreover, top management will commit itself to acquiring energy-efficient equipment and devices needed for any aspect of manufacturing. At the institutional level, a proper organisational structure should be adopted by the firm, in which the functions of the energy unit (department) and energy audit units are clearly defined. In addition, the structure should indicate that there is a relevant feedback or evaluation process built in the system.

To summarise, energy conservation (technical and organisational) is an essential component of the overall manufacturing system if a firm is really interested in improving the efficiency of energy use. For the cement plants in Jordan, several case studies in this regard will be conducted and their anticipated outcome should prove the advantages of energy management procedures on the manufacturing system.

4.3.5 Examination of Important Points

This section is intended to highlight some important points to be examined in this research prior to a detailed description of results and the findings, which will follow in the next chapters.

1) Monitoring energy costs, building statistical and economic models, and implementing energy management procedures in cement plants in Jordan is carried out to find out if it is cost-effective and useful in improving the utilisation of energy in these plants. Moreover, a comprehensive or integrated approach, which takes technical and institutional aspects into consideration, for energy conservation in the cement industry is examined to find out if it is a viable tool for improving the efficiency of energy use.
2) For an industry with such a high-energy consumption rate (and consequently high energy cost component) the efforts related to energy management have to be appreciated and somehow recognised by top management. Moreover, these efforts have to become built-in and permanent management tools for cost effectiveness. This aspect is examined in the next chapters of this research, along with the question of energy management as a permanent and an important component of overall business management of the company.
3) The research work examines if energy management needs to be properly integrated within the overall business management function of the company. This entails a defined corporate structure for EMS with top management commitment and adequate resources. Among the resources needed, in addition to qualified manpower, are the statistical tools and the experimental set-up to investigate energy conservation measures. The practical cases of

energy conservation as well as the case studies carried out at JCF and none presented in the following chapters are used to prove the success of EMS at JCF.

4) The research work further examines the presence of an overall atmosphere of energy conservation awareness. The EMS developed by the researcher is based on the condition that feedback is provided to top management. Top management, in turn, is using energy auditing, conservation measures and related projects in formulating policies and making business decisions.

4.5 Conclusion

This chapter has explained in some detail the research approach adopted to address the issue of energy management and conservation in the cement industry in Jordan. The following chapter begins the detailed presentation and discussion of energy costing in the industry on which this study is focused.

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Chapter Five

Energy Costing of Cement

Industry in Jordan

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Chapter Five

Energy Costing of Cement Industry in Jordan

5.1 Introduction

The Jordan Cement Factories Company was established in December 1951. It undertakes all the necessary activities to produce cement and sell it, both in the domestic market and abroad. In the beginning of the eighties the Southern Cement Company was established with the aim of producing cement mainly for outside markets. In the mid-eighties, the two companies were merged into one company.

The production cost of cement is affected by several factors, which include: type of process used, energy, availability of raw materials and the management system adopted by the company. Cement industry is considered an energy intensive industry, because the most important cost element is that of energy.

In this chapter a detailed analyses of the cement production cost in Jordan Cement Factories (JCF) will be performed to investigate the contribution of each cost element to the total production cost and to demonstrate the important contribution of the energy cost to the total cost of cement manufacturing for the period 1985-1992. Also the effect of inflation will be considered in this analysis. Based on the results of this analysis, the future energy costs for cement production will be discussed.

It is worth mentioning that energy costing analysis for the cement industry is an essential step in evaluating the cost-effectiveness of energy management. Therefore, this chapter is presented before other chapters dealing with detailed energy management aspects, to demonstrate the importance and validity of the subsequent research efforts.

Moreover, the analysis of the production cost elements and the future trends of energy cost and prices gives a platform for the statistical and economic models (which will be discussed in chapter 7). Energy prices play a dominant role in determining the cost of each tonne of cement produced.

5.2 Cost of Energy in Cement Manufacturing

5.2.1 Worldwide

It is estimated that the world primary energy consumption for cement production is around 2% of annual world energy consumption. Energy costs are in the range of 30% to 40 % of total cement manufacturing costs (World Energy Council, 1995). The following table (5.1) shows the share of energy consumption of the different production stages of cement for a typical Portland cement plant (dry process).

Table (5.1)

Energy Consumption in a Typical Portland Cement Plant (%)

Production Stage	Fuel (MJ/ tonne clinker)	Electricity (kWh / tonne Cement)	Total (MJ/ tonne Cement)
Raw Material Collection	1 %	5%	2 %
Raw Material processing		33 %	8 %
Pyroprocessing	99 %	22 %	79 %
Clinker Grinding		38 %	10 %
Conveying, packaging, ...etc.		5 %	1 %
Total	3535	110	4517
Share of Total	75 %	25 %	100 %

Source: World Energy Council (1995).

The total energy consumption for the European cement sector is estimated at 578 PJ / year, corresponding to 2 % of total final energy consumption in the 12 EC countries. The total consumption is divided into fuel consumption representing 88 % and electricity consumption accounting for the remaining 12 %. As for specific energy consumption in these countries, it is estimated that it is around 3.38 MJ/ Kg cement (Cowi Consult, 1993). The difference between the share of fuel and electricity in the total energy consumption as presented in Table (5.1) and the findings of the European study need to be investigated and thoroughly verified which is outside the scope of this research.

The greatest proportion of the total manufacturing costs is made up of the cost of feed materials to the cement mills, which is the clinker. In cements with several main constituents the selection of mix formulation therefore has a great influence on minimising the manufacturing cost, but when producing Portland cement using clinker produced by the same company, there is little room for manoeuvre. Ellerbrock (1994) goes on to emphasise the importance of the so-called fixed costs when assessing the manufacturing costs. These include the costs of the plant and the capital tied up in the spare parts as well as the cost of providing the energy. Some of these costs can be influenced. They include expenditure on maintenance and repair and the energy costs which for cement amount to between 30% and 40 % of total manufacturing costs and differ very widely both regionally and between individual works. In view of this very high percentage, the cement industry has been making great efforts in the last 40 years to lower energy consumption and cost. The total energy cost for cement manufacture is divided between the costs for fuel and electrical energy. Ellerbrock (1994) reports that improved combustion technology and efficient use of waste heat have more or less halved the consumption of fuel energy per kg clinker in Germany, and the specific fuel energy costs have been reduced for the same fuel energy consumption through the use of cheap secondary fuels. However, the specific electrical energy consumption in, for example, West German cement works rose from about 80 kWh/tonne cement in 1960 to approximately 110 kWh/tonne cement in 1985. This increase has resulted from increased expenditure on environmental protection measures to lower fuel energy consumption, commissioning of modern grinding plants for coal instead of fuel oil, automation of the operation of cement works plants, and the fact that it has been necessary to improve the fineness of individual products, to maintain performance, especially for cement with several main constituents. Due to the rise in the price of electrical energy in many countries, and the increase in consumption of electrical energy, in some works in Europe and also in other countries, the costs of electrical energy exceed the fuel costs. In recent years, therefore, efforts within the cement industry to reduce energy costs have focused primarily on measures to save electrical energy (Ellerbrock, 1994).

5.2.2 In Jordan

Cost accounting and analysis are very useful for planning and controlling of a company's operation including production, inventory valuation, and profit determination. However, once energy costing is considered, particularly for energy intensive industries, like the cement industry, then issues like energy conservation measures appear to be of great importance. This is particularly so, because, in the cement industry, in general, energy costs amount to around 35 % of the overall production cost. Therefore, any improvement in the efficiency of energy use will have a noticeable impact on the overall cost of the manufacturing system, which indicates that the energy cost represents a serious challenge to the cement producers.

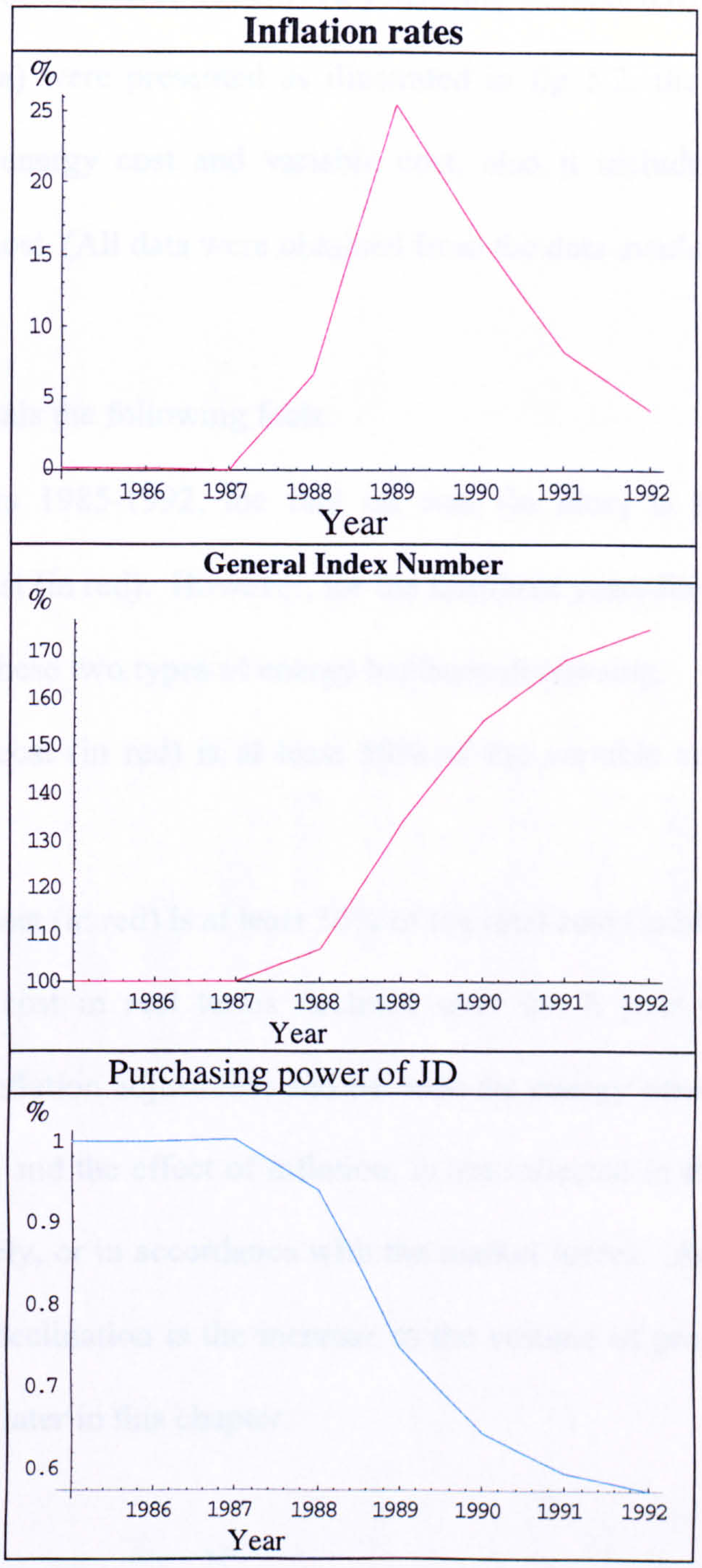
Two previous studies commissioned by JCF (MMIS, 1994; AGCO, 1994) as well as all internal studies of JCF indicated that, on the average, the energy cost component (fuel and electricity) constituted about 60 % of the variable cost of producing one tonne over the period 1985-1993. Moreover, the ratio of energy cost to total production cost was about 34%.

5.3 Cement Production Cost Analysis

5.3.1 Main economical parameter in Jordan

In this work we will analyse the cost elements of the cement produced at JCF factories taking into consideration both raw cost data and the data after adjusting for inflation, this costing analysis will be based on the data available in Table (5.5) "Cost Centres in Cement Production". All the data related to the cost of cement were obtained from costing section, department of finance C/O Ziad Shadeh. For the process of inflation adjustment Figure (5.1) provides the inflation rates, the general index numbers, and the purchasing power of J.D. for the years 1985-1992 with 1985 as base year and also table 5.4 gives inflation rates for the years 1990-1998(Ministry of planning and central bank of Jordan yearly statistical series 1964-2000). General index number is a statistical tool used to show relative changes in prices, productivity, cost etc with respect to a base year selected and subsequent fluctuations are calculated in terms of this base period. In Jordan it is based on prices of 745 consumer goods and services categorized in four groups: 1) food items 2) clothing and foot wear 3) housing 4) other goods and services, the inflation rate is the percentage change of this index. Moreover, this graph provides a plot of these numbers as functions of time. It is clear that the inflation rate was increasing up to the year 1989, and then it started decreasing but remained high until 1991. The sudden jump in the inflation rate during the period 1988-1990 was due to the foreign debt crisis, which erupted in Jordan in 1988. This crisis caused the average exchange rate to drop from around $3 per JD1 in 1987 to $1.7 in 1989 and $1.5 in 1990 (Central Bank of Jordan, Monthly Statistical Bulletin, June 1993). Thus, the purchasing power of the J.D. has been decreasing rapidly, and the JD lost almost half of its value during that period, as can be seen in the graph on the following page.

Figure (5.1) : The inflation rates, the general index numbers, and the purchase power of J.D. for the years 1985-1992 with 1985 as base year



Source: Central Bank of Jordan, yearly statistical series 1964-2000

5.3.2 Relative Contribution of energy cost

The energy cost data for the period 1985-1992 consisting of electricity cost and fuel cost (raw data and adjusted data) were presented as illustrated in fig 5.2, the presentation including comparison between energy cost and variable cost, also it includes comparison between energy cost and total cost. (All data were obtained from the data available in table 5.5)

Figure (5.2) reveals the following facts:

i. For the years 1985-1992, the fuel oil cost (in blue) is higher than that of electricity cost (in red). However, for the last three years the difference between the costs of these two types of energy has been decreasing.

ii. The energy cost (in red) is at least 50% of the variable cost (in blue) during same period.

iii. The energy cost (in red) is at least 30% of the total cost (in blue).

iv. The energy cost in real terms declined over the 8 year period under study because of inflation adjustment and because the energy prices controlled by the Government, and the effect of inflation, is not reflected in the prices directly or proportionately, or in accordance with the market forces. Another reason of the energy cost declination is the increase in the volume of production, which will be discussed later in this chapter.

Figure (5.2) Relative contribution of energy cost

The production of cement is generally affected by a number of factors which include, amongst others: production technology, capital investment, energy resources, availability of raw materials, the proximity of raw materials to the factory, the distribution network, the form of the final product (bagged vs. unbagged cement) and the management system of the company and its operations.

The most important cost element that appears to be dominating the cement industry is that of energy since, as stated above, more than 50 percent of the variable costs are for energy. However, the heavy use of a number of energy sources, (fuel oil, electricity, diesel) poses environmental challenges to cement producers and adds considerably to operating costs without improving production.

Another important cost element in the production of cement is usually related to maintenance and spare parts. The magnitude of machinery required in the cement production during all stages gives an idea about the complicated and expensive job of maintaining them in an operating condition. Moreover, the costs of maintenance are positively associated with the age of the machinery itself.

Equally important is the way in which the different cost elements associated with the production process are divided, amongst the different stages, within the overall costing structure of the company.

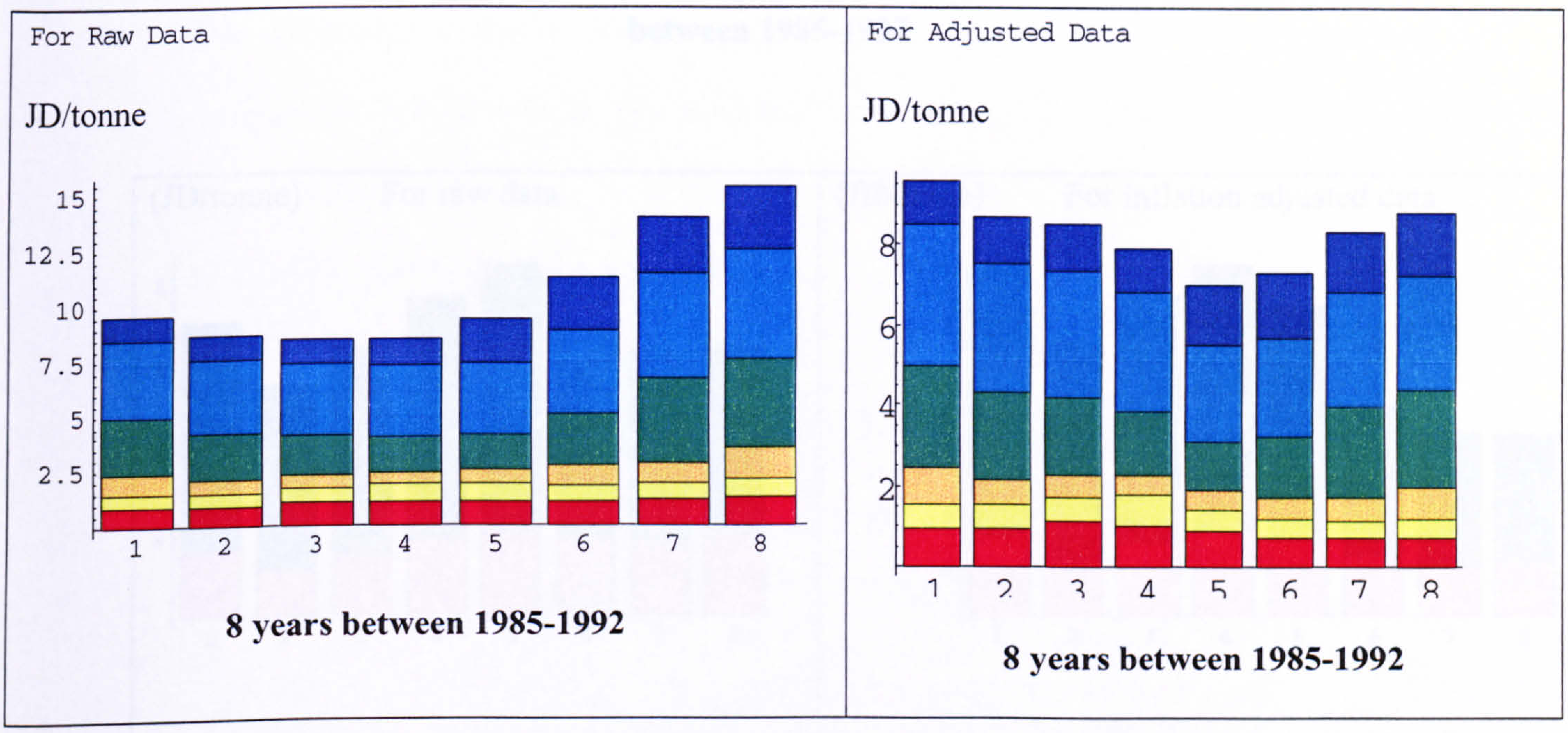
5.3.3 Cement Variable cost analysis

As it's revealed from the previous analysis, the variable cost of cement in JCF represents more than 50% of the total production cost. The variable cost usually defined as the direct cost of production, which fluctuates, with the level of production, (B. Mckenna et al, 1974).

Figure (5.3) presents the variable cost per tonne, components for the years 1985-1992 (obtained from table 5.5) ordered from bottom to top as follows: raw material, direct labour, maintenance, electricity, fuel, and other variable cost. The numbers 1, 2, ...,8 represent the years 1985,...,1992 respectively. It is clear from this figure that

i. Using raw data, the total variable cost slightly declines in 1985, remained stable in the period 1986 – 1988 and starts increasing in 1989 and thereafter. However, after adjusting for inflation, the total variable cost decreases up to the year 1989 then it starts increasing in 1990. This indicates that a large part of the increase in total variable cost was due to inflation.
ii. The cost of fuel oil is the largest one among all variable cost components.
iii. The costs of raw material, direct labour, are almost fixed over time.
iv. The costs of the other four components, namely, maintenance, electricity, fuel, and other variable cost are non-decreasing over time.

Figure (5.3) Stacked bar chars for variable cost components

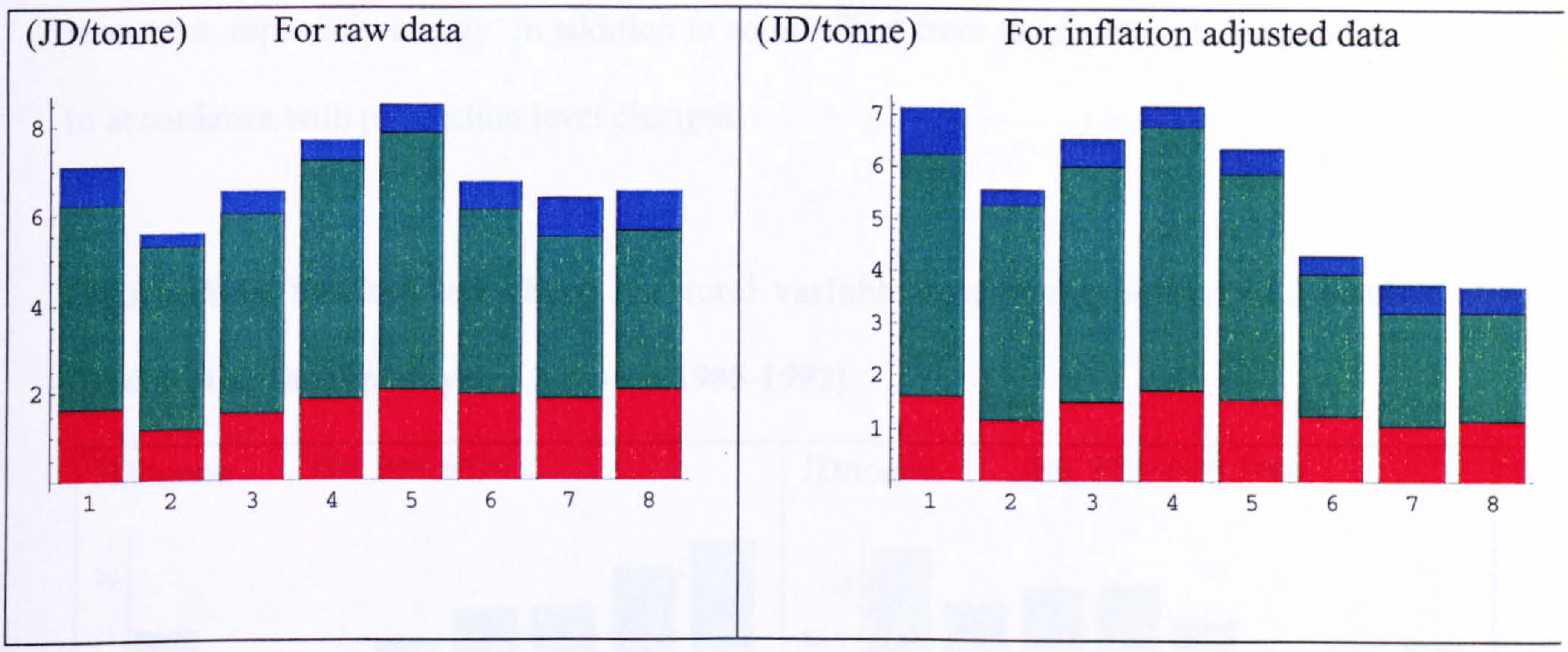


5.3.4 Cement Fixed Cost analysis

Overall efficiency in the production process and the extent of actual equipment utilisation compared with design levels are also very important factors affecting the cost of cement production. This is very much related to the allocation of the fixed cost based on the level of production output, which should reach a minimum at 100% capacity utilisation levels reflecting the concept of economy of scale. Fixed cost usually defined as the overhead cost, which don't vary with the value of production, e.g.: depreciation, rent, etc. (B. Mckenna, 1974) et al.

Figure (5.4) presents the fixed cost components (obtained from table 5.5) ordered from bottom to top as follows; salaries, depreciation, and other fixed cost. It is clear from this figure that depreciation has the largest contribution among all fixed cost components. Moreover, the raw data and the inflation-adjusted data show the same patterns and the same cost scale.

Figure (5.4): Stacked bar chars for fixed cost components for a period of 8 years between 1985-1992



5.3.5 Cement Total Cost analysis

The total cost of production per ton of cement is made up of the following categories that were chosen in harmony with the accounting system adopted for internal auditing (MMIS, 1994):

- Variable manufacturing cost / tonne
- Fixed manufacturing cost / tonne
- Administrative cost / tonne
- Marketing and selling cost / tonne
- Financial cost / tonne

Figure (5.5) presents the total cost components (obtained from table 5.5) where total variable cost at the bottom and total fixed cost at the top. It is clear from this figure that the total variable cost is larger than the fixed cost. Moreover, the raw data and the inflation adjusted data show different patterns since the raw data shows that the total cost is increasing, while after adjusting for inflation the total cost is slightly decreasing. This difference in the pattern is due mainly to the changes in the variable cost components, which reflects the importance of managerial efficient use of variable resources, especially energy. In addition to some effect from the fixed cost components in accordance with production level changes.

Figure (5.5): Stacked bar charts for total variable cost at the bottom and total fixed cost at the top. (8 years between 1985-1992)

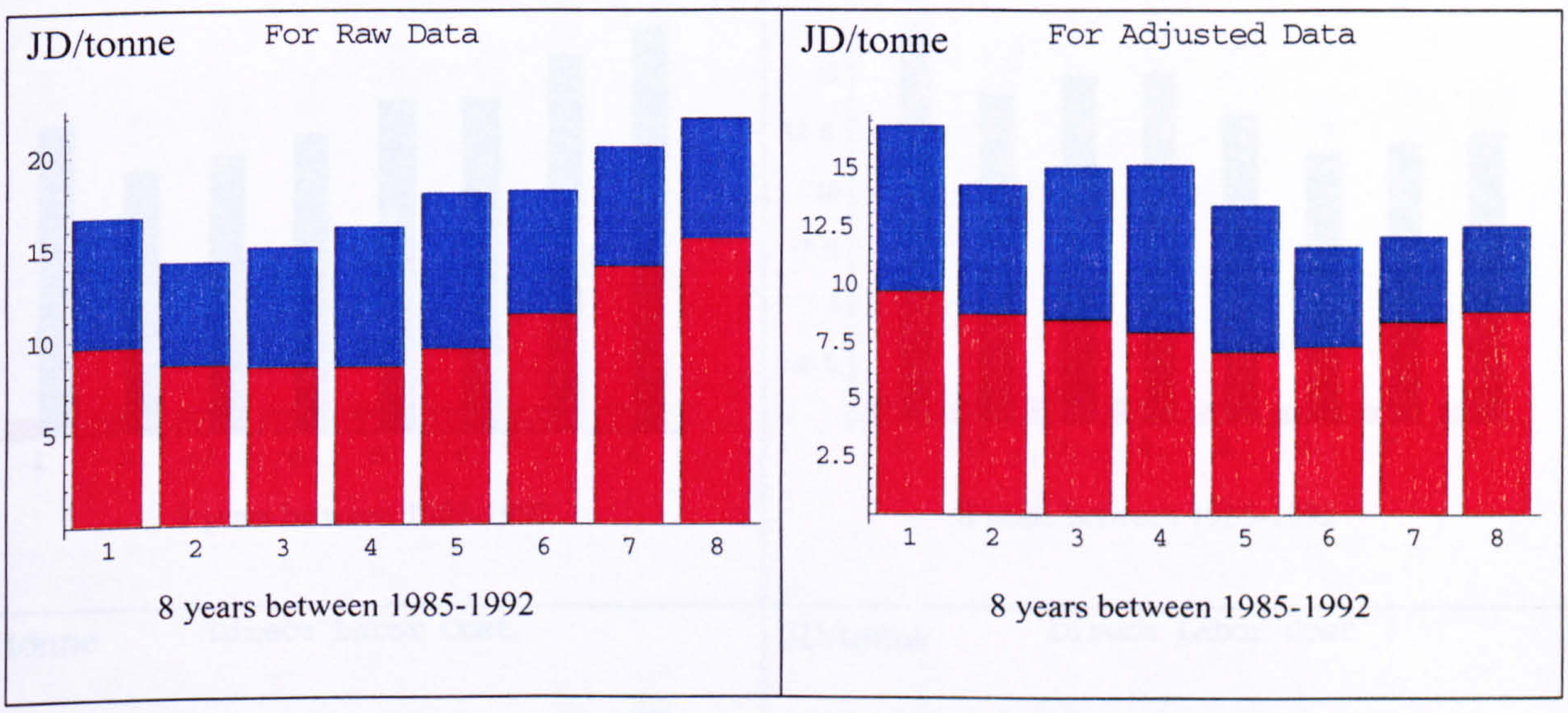


Figure (5.6) presents the relative cost of each component (in red) to the total cost (in blue) based on both raw data and inflation-adjusted data. It is clear from this figure that

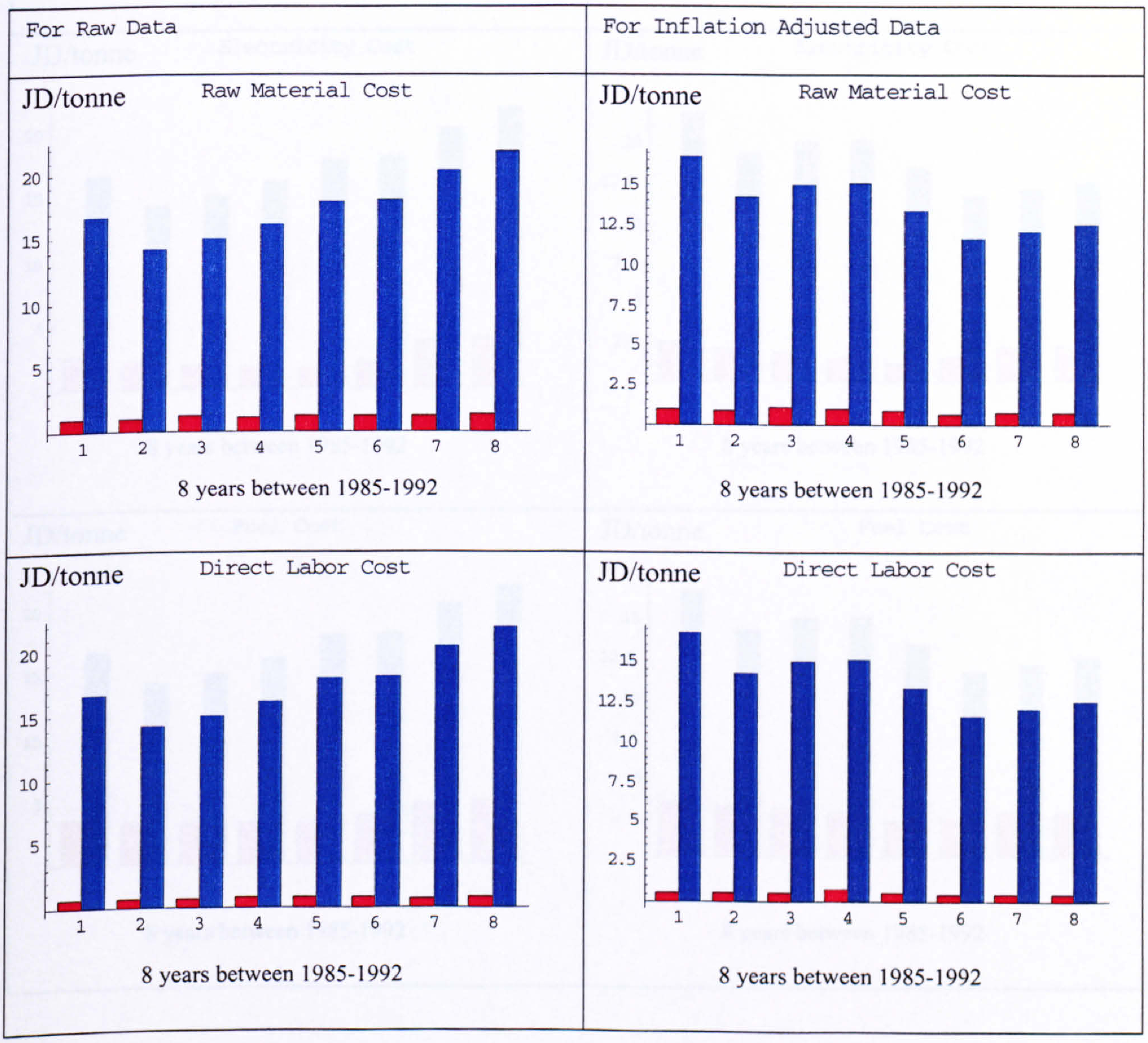
i) There is almost no difference between the relative costs based on raw data and inflation adjusted data

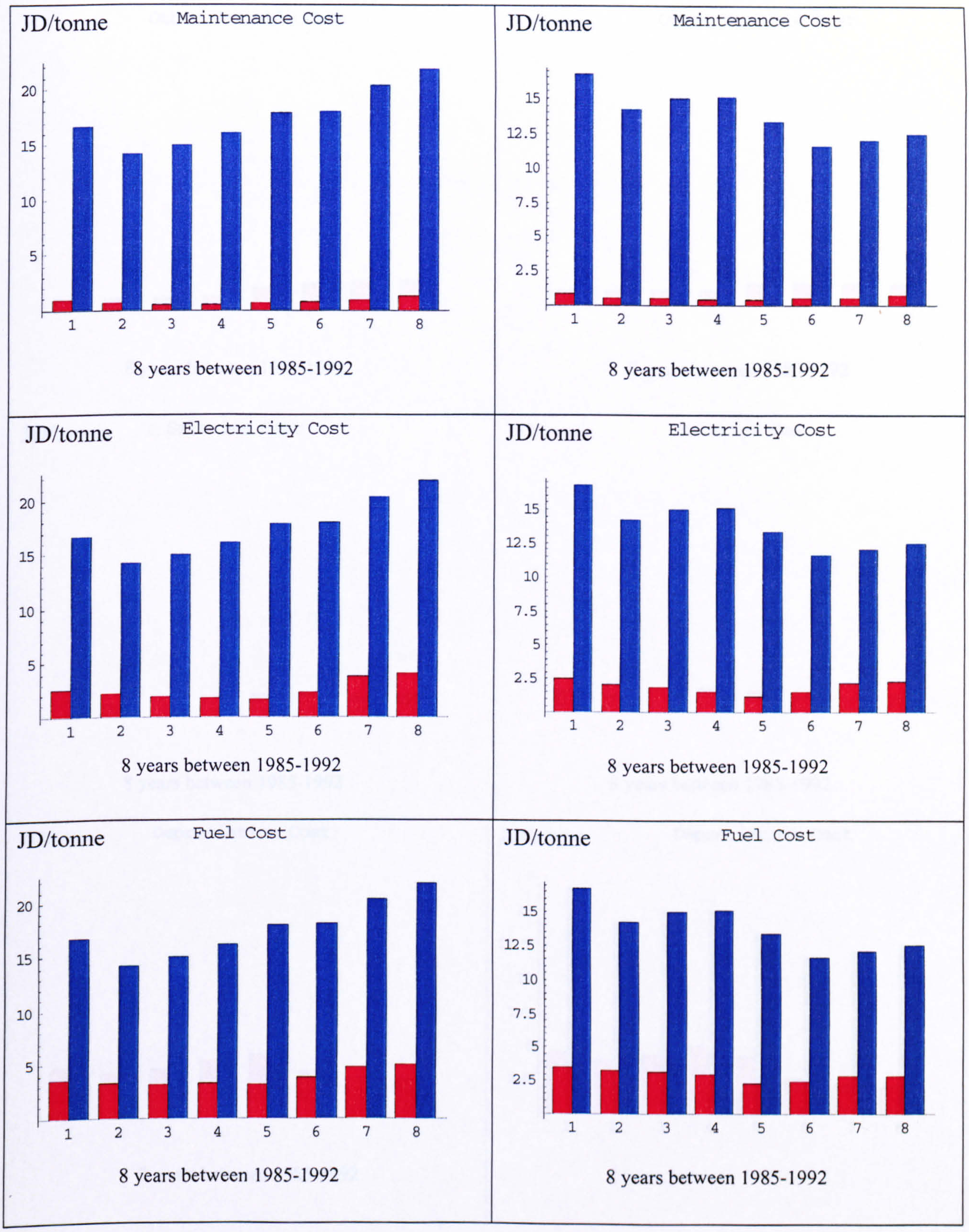
ii) The cost scale based on inflation-adjusted data is smaller than that based on raw data because of inflation adjustment.

iii) The total cost based on raw data is increasing, while that based on inflation adjusted data is slightly decreasing because the prices of the main components of production which is energy is a managed price by the government, and thus prices do not reflect the actual free market price. The government does not reflect the effect of inflation and the variations of the prices of goods and services on some of the cost component items.

Figure (5.6): Relative Cost of Each Component to Total Cost

(8 years between 1985-1992)




JD/tonne
Maintenance Cost
8 years between 1985-1992
JD/tonne
Maintenance Cost
8 years between 1985-1992
JD/tonne
Electricity Cost
8 years between 1985-1992
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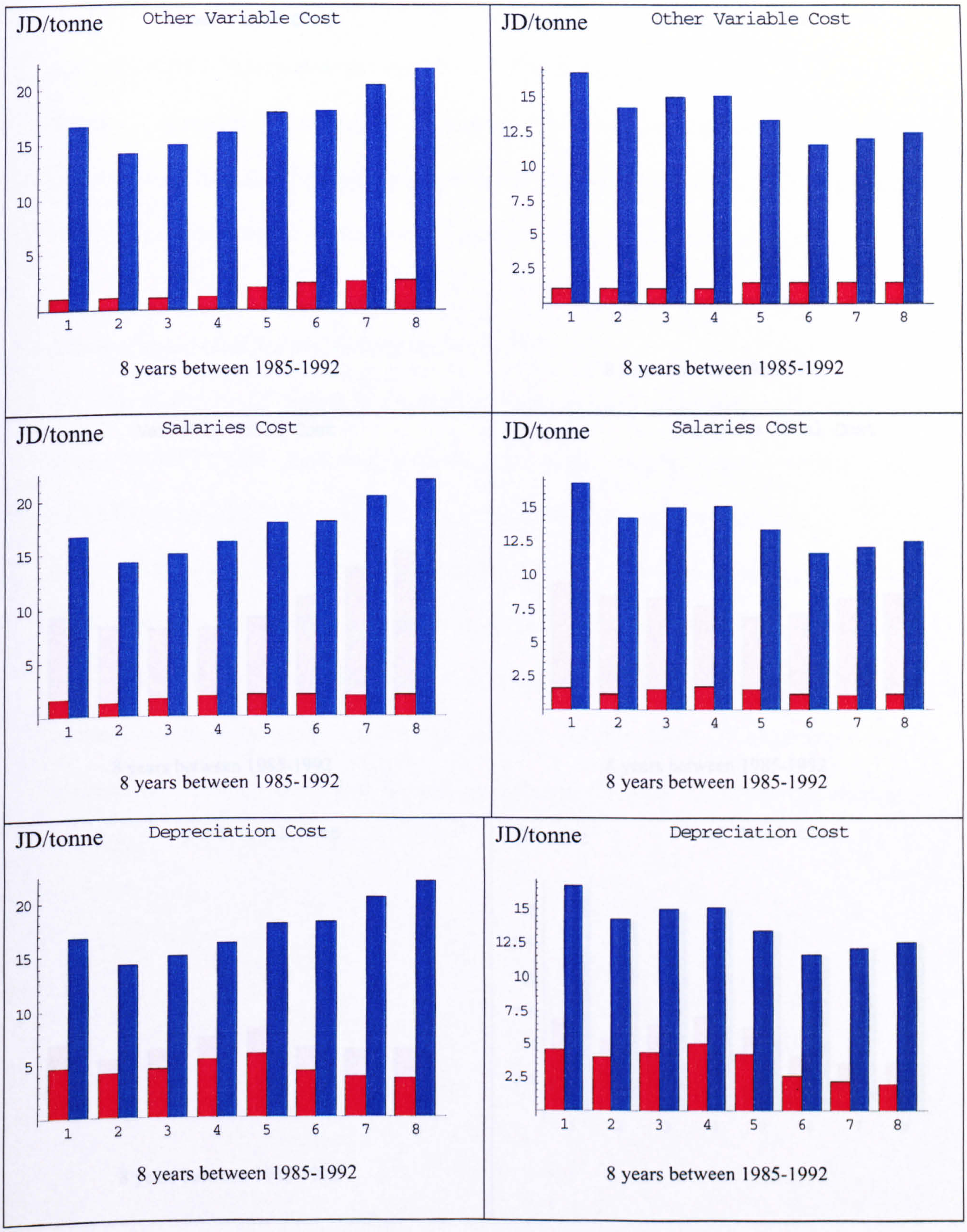
Fuel Cost
8 years between 1985-1992


JD/tonne
Other Variable Cost
8 years between 1985-1992
JD/tonne
Other Variable Cost
8 years between 1985-1992
JD/tonne
Salaries Cost
8 years between 1985-1992
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Salaries Cost
8 years between 1985-1992
JD/tonne
Depreciation Cost
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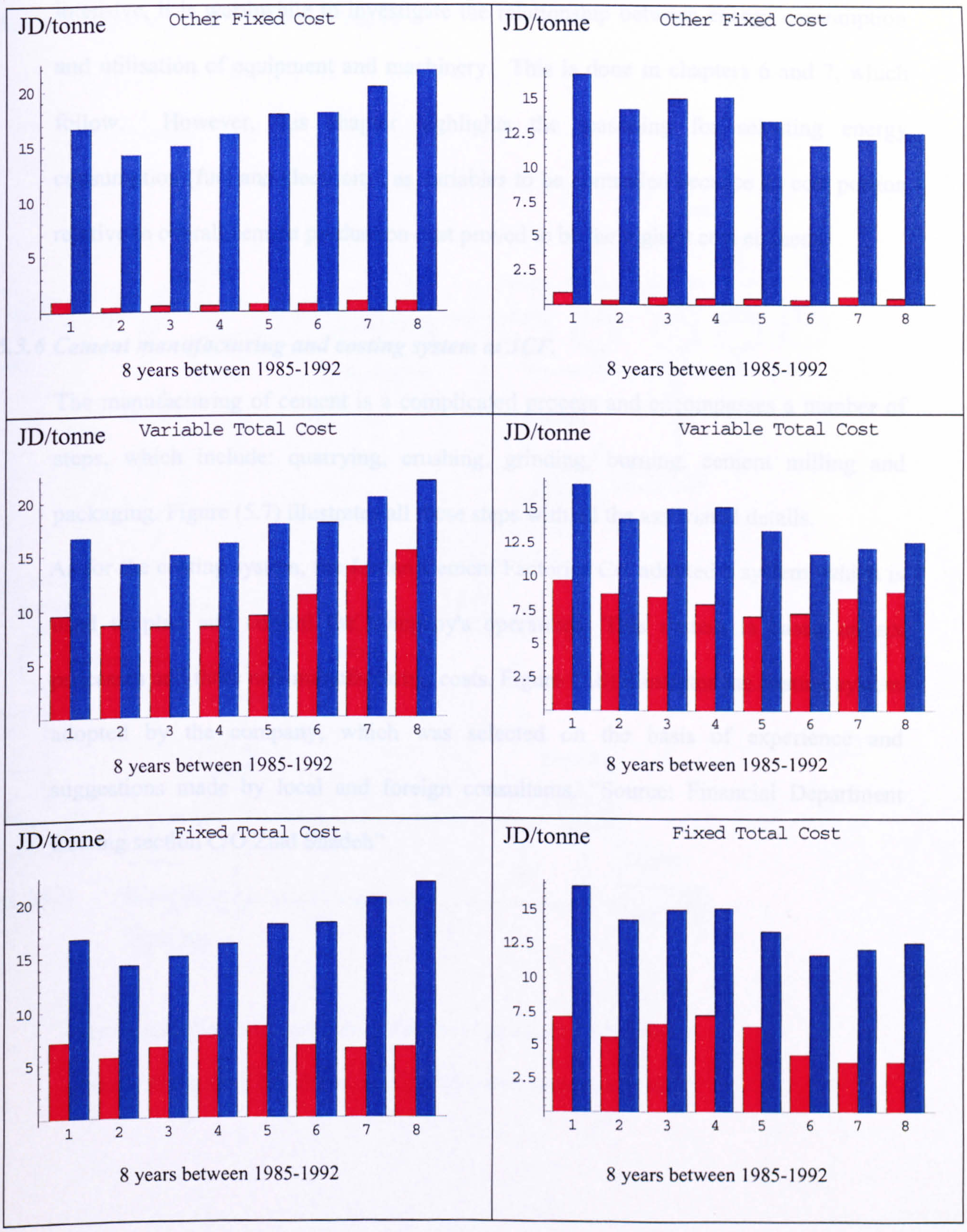
JD/tonne
Depreciation Cost
8 years between 1985-1992



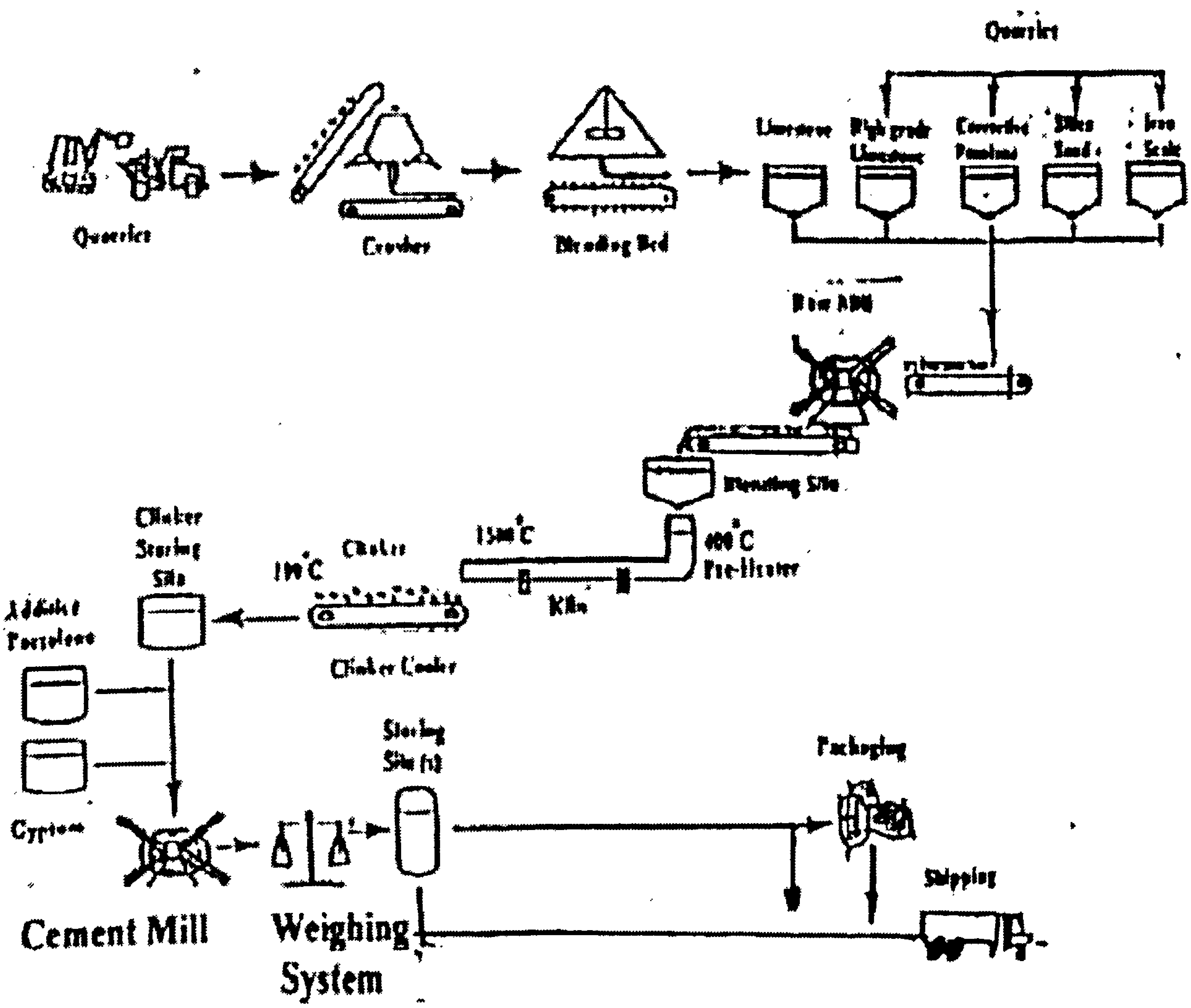
Therefore from the presented analysis, it is clear that energy (thermal and electricity) cost is an important cost element, which warrants management's monitoring and control. Moreover, as cement industry is both capital-intensive as well as energy-intensive, it is worthwhile to investigate the relationship between energy consumption and utilisation of equipment and machinery. This is done in chapters 6 and 7, which follow. However, this chapter highlights the reasoning for selecting energy consumption (fuel and electricity) as variables to be controlled because its cost portion relative to overall cement production cost proved to be the highest cost element.

5.3.6 Cement manufacturing and costing system at JCF.

The manufacturing of cement is a complicated process and encompasses a number of steps, which include: quarrying, crushing, grinding, burning, cement milling and packaging. Figure (5.7) illustrates all these steps with all the associated details.

As for the costing system, the Jordan Cement Factories Co. adopted a system, which is used to plan and control the company's operations. This system is based on six processes and three non-manufacturing costs. Figure (5.8) illustrates the costing system adopted by the company, which was selected on the basis of experience and suggestions made by local and foreign consultants. "Source: Financial Department Costing section C/O Ziad Shadeh"

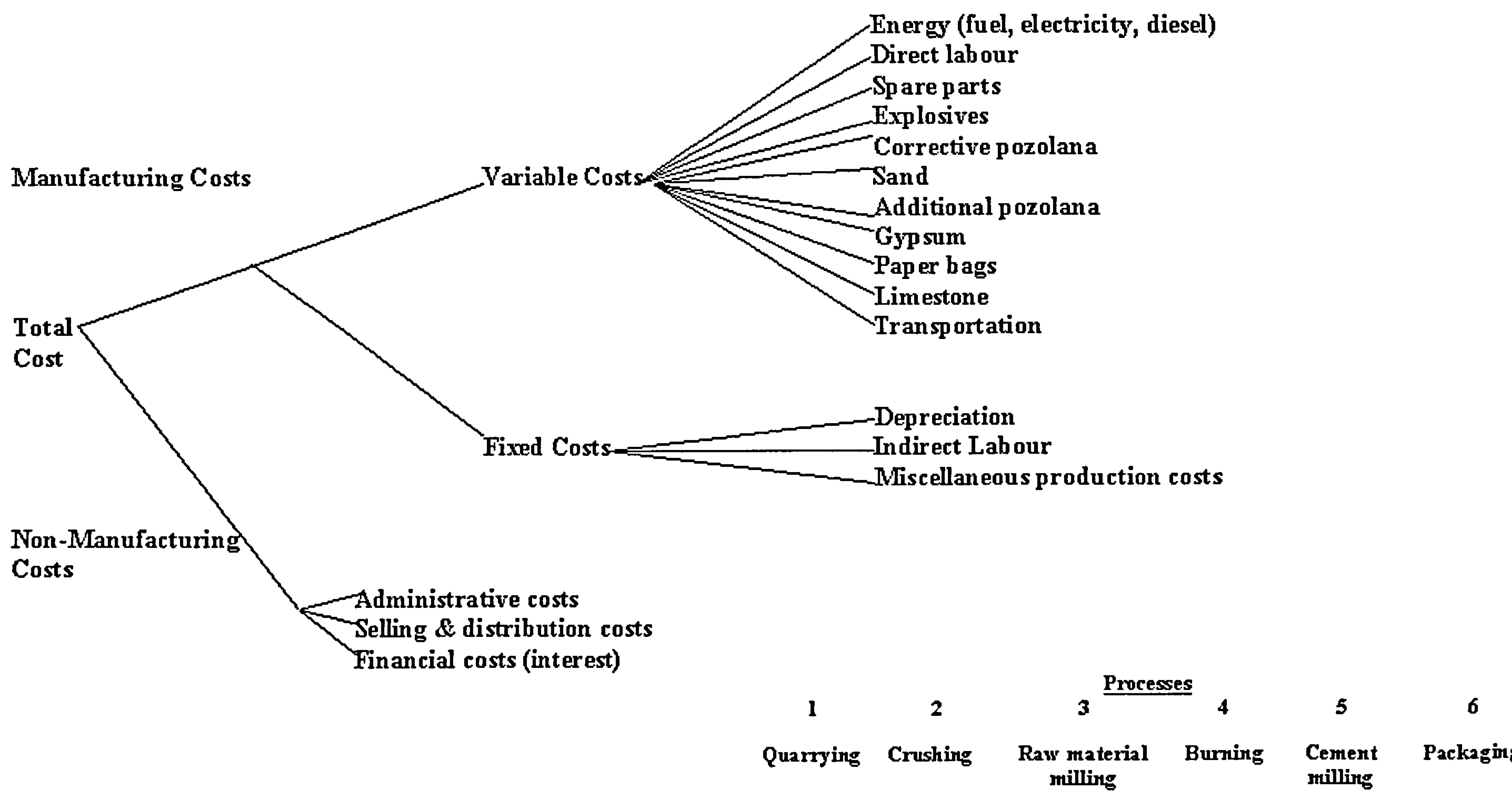
Fig (5.7) Cement Manufacturing Process



Schematic diagram for Fuhais Factory/ production line no. 6

Source Kobe Steel Ltd Technical Specification Handbook (1980)

Figure (5.8) JCF Production Costing System



The variable cost of cement production involves six major processes (the steps mentioned above) as illustrated in Figure (5.8). These processes represent cost centres whereby it is possible to find the total manufacturing cost associated with each of these processes. Consequently the cost per tonne of production for each process can be calculated. The following assumptions are made for distributing costs among the various manufacturing cost centres (based on the company's historical records):

1. Salaries are taken as 72% fixed and 28% variable.
2. The variable cost per ton of raw materials produced is multiplied by a factor of 1.65 to allow for losses in clinker burning.

Table (5.2) illustrates the distribution of annual cement manufacturing costs at different steps of production (processing centres) for the year 1992. These variable cost data were collected from actual records of the financial department. Costing section C/O costing accountant Mr. Ziad Shadeh.

Table (5.2)
Distribution of Cement Variable Manufacturing Costs for Fuhais plant (1992)

Process Code	Process	Cost (JD)	Notes	% of Total
100	Quarries	876139	Quarrying & transportation	3.7
200	Crushing	277077	Raw material preparation	1.2
300	Grinding	2241240	Silica sand, iron powder and corrective pozzolana	9.5
	Subtotal	3394456	Subtotal	--
400	Burning	10744897	(conversion factor between raw ground material and produced clinker is 1.0511487)	45.3
500	Grinding	4956365	Cost for grinding produced bulk cement	21.0
		1588288	Produced bulk cement (ton)	--
600	Packaging	4553215	Cost of multi ply sacks (JD)	19.3
		1603022	Delivered cement (ton)	
	Total	23648933	Grand total cost for all processes	100

Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

It can be seen from this table that the cost of quarrying and transportation accounts for only about 3.7% while the cost of crushing of raw materials accounts for only around 1.2% of the total variable production cost. However, burning cost amounts to around 45% of the total variable production cost. This process is the highest cost item in the production of cement. This is followed by the grinding of produced bulk cement (process code 500), which constitutes about 21%. Finally the cost of packaging constitutes 19.3%. This means that the cost of energy (process codes 200,300,400 and 500) constitutes around 77% of the total variable cost.

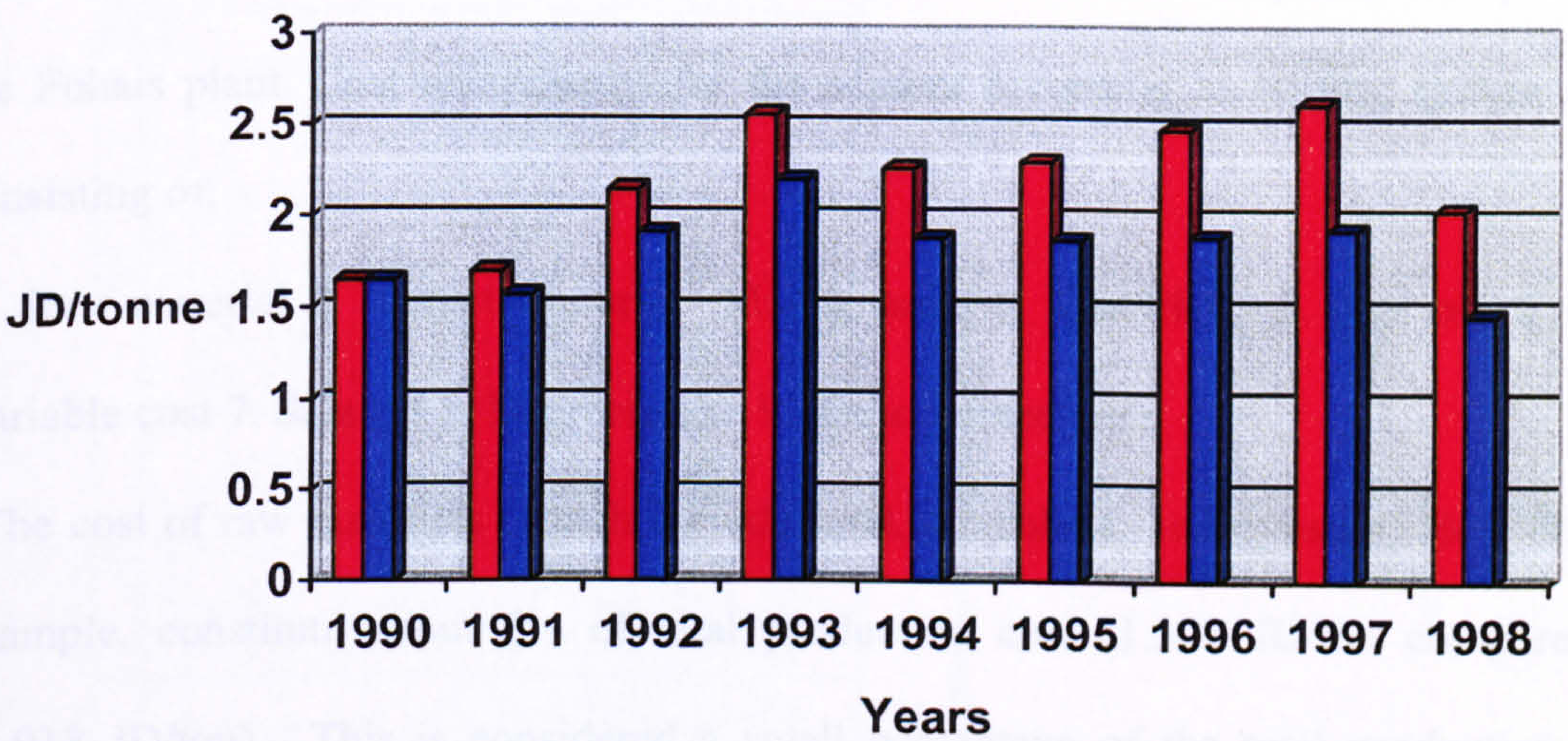
As mentioned above, the cost of transporting raw materials is included within the first manufacturing process (process code 100). However, the cost of transporting and distributing the finished product (Sacked Cement) is not included because of two reasons. First, it is not within the manufacturing process of the plant. Second, JCF started in 1999 to deliver cement to the cement traders and contractors at plant. This means that the cost of transporting and distributing cement is no longer borne by JCF but by the purchasers. Nevertheless, the following Table (5.3) illustrates the evolution of the average cost of transporting and distributing cement to final users based on 1990 prices. Table (5.4) provides the inflation rates for the years 1990-1998. Figure (5.9) provides bar chart, which illustrates the evolution of cost of transporting and distributing cement to final users. Red bars represent the raw data. Blue bars represent adjusted data according to inflation rates.

Table (5.3): Average transport and distribution current costs of JCF

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Current cost JD/tonne	1.65	1.7	2.15	2.56	2.26	2.3	2.48	2.62	2.04
Adjusted cost JD/tonne	1.65	1.57	1.91	2.20	1.88	1.87	1.89	1.93	1.46

Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

Figure (5.9): Bar chart of transport and distribution cost of JCF



It is clear from this figure that the raw transport and distribution cost of JCF is always higher than that of the corresponding inflation-adjusted cost because the inflation effect is not reflected directly or proportionately in the current cost, but may be slightly reflecting the decreasing trends in the inflation rates as shown in table 5.4. It is worth mentioning here that one of the major costs of transport is the energy cost and if this cost is considered in the energy cost of cement production, this will increase the contribution of energy to the total cost of the production of cement.

Table (5.4): The inflation rates

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
% Inflation rate	8.2	4.0	3.3	3.6	2.3	6.5	3.0	3.1	0.57

Source: ministry of planning, C/O Dr Tayseer Al-Sumadi

5.4 Detailed Total Cement production Cost at Fuhais Plant

5.4.1 Breakdown of the cost elements of cement:

Table (5.5) gives all the details of variable and fixed costs of the production process at the Fuhais plant. Cost components for the cement according to costing system at JCF consisting of:

1. Raw material 2. Direct labour 3. Maintenance 4. Electricity 5. Fuel oil 6. Others Variable cost 7. Salaries 8. Depreciation 9. Others fixed cost.

The cost of raw materials (which include sand, pozzolana, and gypsum) for 1992 for example, constitute about 6% of total production cost (1.303 JD/ton compared to 21.918 JD/ton). This is considered a small percentage of the total production cost compared to other industries where it constitutes about 50-60% of total production cost.

Table (5.5)
Cost Centres in Cement Production
(JD/ton)

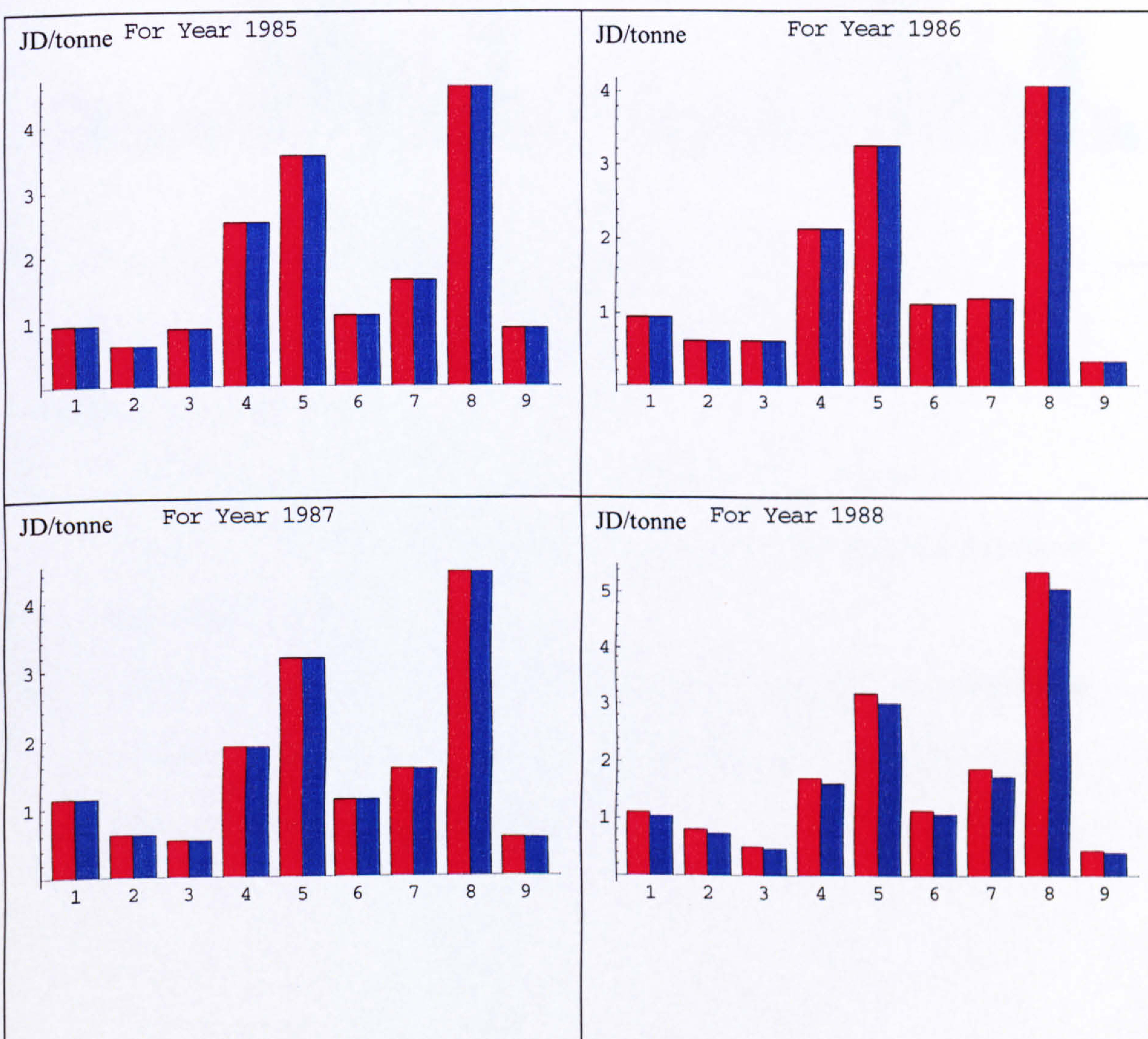
	Description	1985		1986		1987		1988		1989		1990		1991		1992	
	Despatch	1528084		1304879		1278026		1083453		1005593		1190001		1268560		1603022	
		1985	%	1986	%	1987	%	1988	%	1989	%	1990	%	1991	%	1992	%
Variable Costs	Raw Materials	0.957	5.73	0.948	6.85	1.147	7.84	1.112	6.90	1.163	6.48	1.136	6.30	1.247	6.13	1.303	5.84
	Direct Labor	0.623	3.73	0.605	4.25	0.612	4.05	0.791	4.91	0.787	4.39	0.737	4.09	0.691	3.40	0.815	3.72
	Main. Prov.	0.879	5.28	0.605	4.25	0.532	3.55	0.490	3.04	0.633	3.53	0.821	4.55	0.935	4.60	1.379	6.29
	Electricity	2.518	15.07	2.135	14.88	1.891	12.60	1.696	10.53	1.598	8.92	2.358	13.08	3.764	18.50	4.110	18.75
	Fuel Oil	3.518	21.07	3.256	22.85	3.165	21.09	3.194	19.83	3.170	17.70	3.807	21.11	4.808	23.63	5.037	22.98
	Others	1.104	8.61	1.112	7.80	1.109	7.39	1.150	7.14	2.048	11.44	2.453	13.60	2.544	12.51	2.752	12.58
	Total Variable Costs:	9.597	57.45	8.681	60.77	8.458	58.36	8.433	52.36	9.399	52.48	11.312	62.73	13.989	88.77	15.396	70.24
Fixed Costs:	Salaries	1.623	8.72	1.188	8.34	1.546	10.32	1.859	11.54	2.079	11.61	1.948	10.50	1.831	9.00	2.058	9.39
	Depreciation	4.608	27.60	4.08	28.63	4.441	29.60	5.372	33.38	5.794	32.35	4.173	23.14	3.639	17.89	3.570	18.29
	Others	0.888	5.20	0.322	2.28	0.559	3.73	0.441	2.74	0.637	3.58	0.601	3.33	0.884	4.35	0.894	4.08
	Total Fixed Costs:	7.1	42.52	5.58	39.23	0.548	43.64	7.672	47.64	8.510	47.52	6.722	37.27	6.345	31.23	6.522	29.76
	Total Operating Cost:	16.607	100.00	14.251	100.00	15.004	100.00	16.105	100.00	17.909	100.00	18.034	100.00	20.343	100.00	21.918	100.00

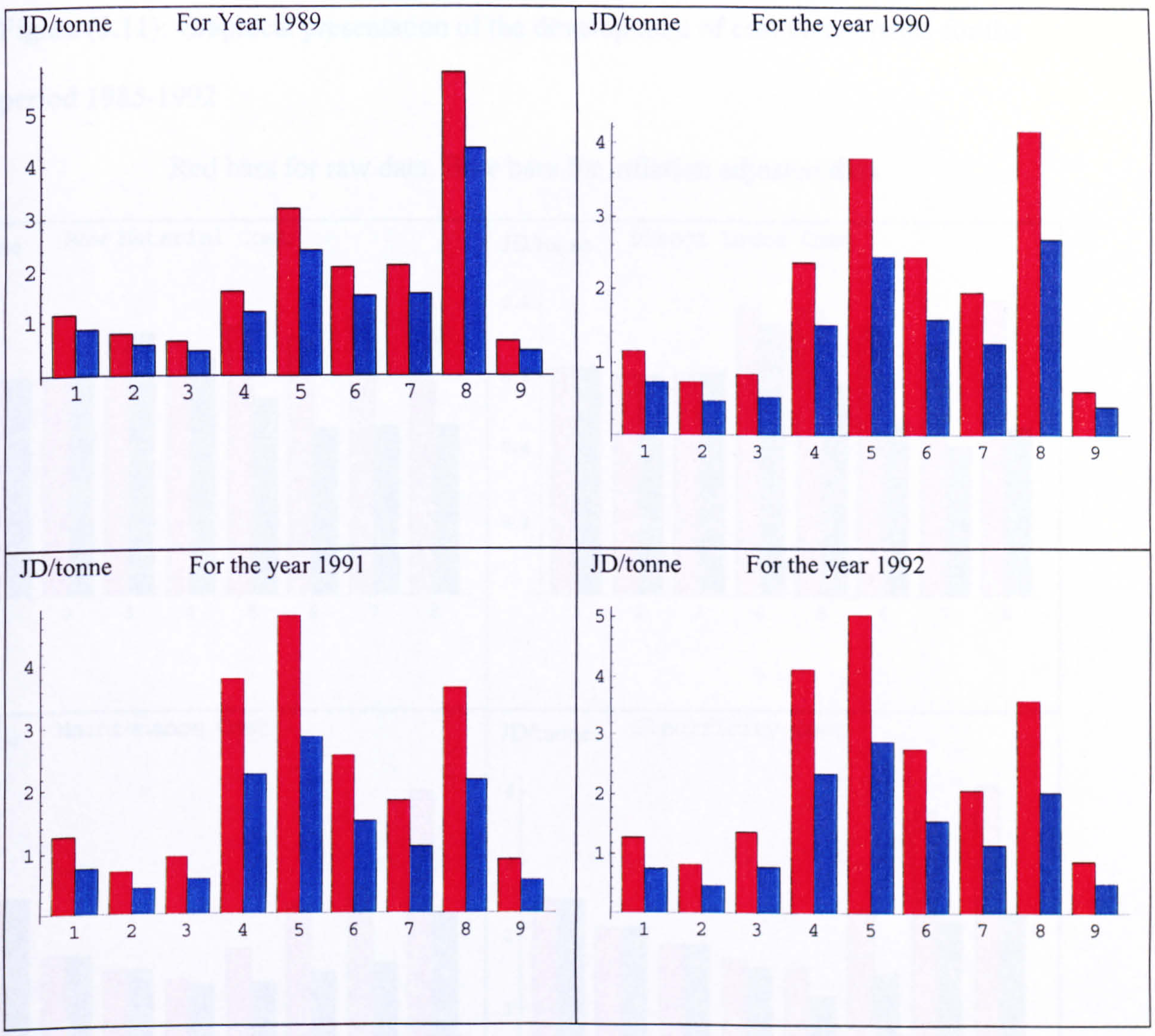
Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

It is useful to investigate the contribution of each element in the production cost of cement and also to investigate the effect of inflation on these cost elements. Figure (5.10) presents the raw data in table (5.5) representing these cost elements together with the inflation-adjusted data.

Figure (5.10): **Graphical presentation of cost components for each of the years 1985-1992 Red bars for raw data. Blue bars for inflation adjusted data**

1. Raw material, 2. Direct labour, 3. Maintenance, 4. Electricity, 5. Fuel oil 6. Others variable cost 7. Salaries 8. Depreciation 9.Others fixed cost





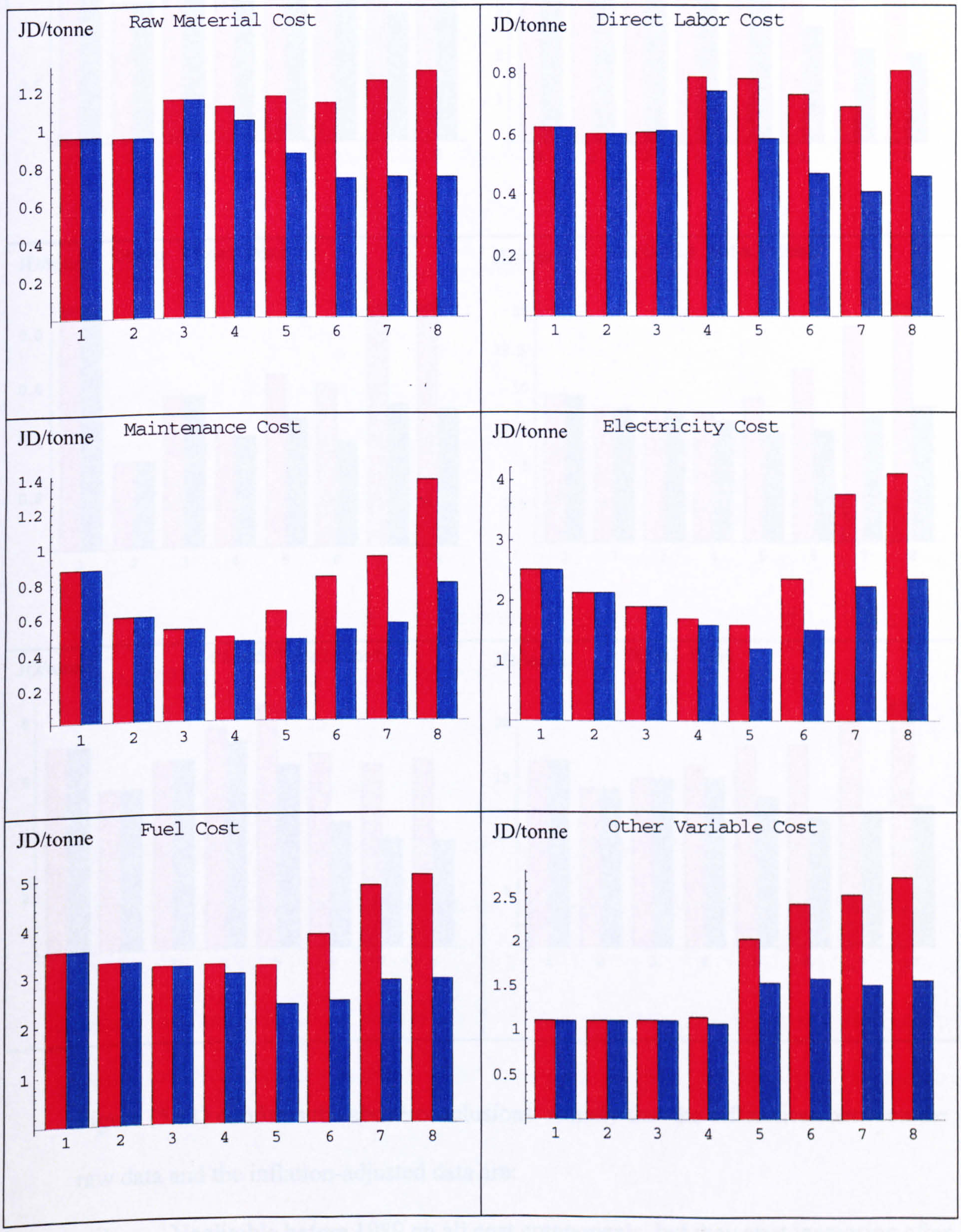
It is clear from Figure (5.10) that the differences between the raw data and the inflation adjusted data are:

i) Negligible before 1989 on all cost components (because of very low or negligible inflation rate), but they start increasing after that as a consequence of high inflation rates.

ii) Component dependent, i.e. they differ from one cost component to another, and to illustrate this we shall take the effect of each component separately in the following analysis presented bellow:

Figure (5.11): Graphical presentation of the development of cost components for the period 1985-1992

Red bars for raw data. Blue bars for inflation adjusted data



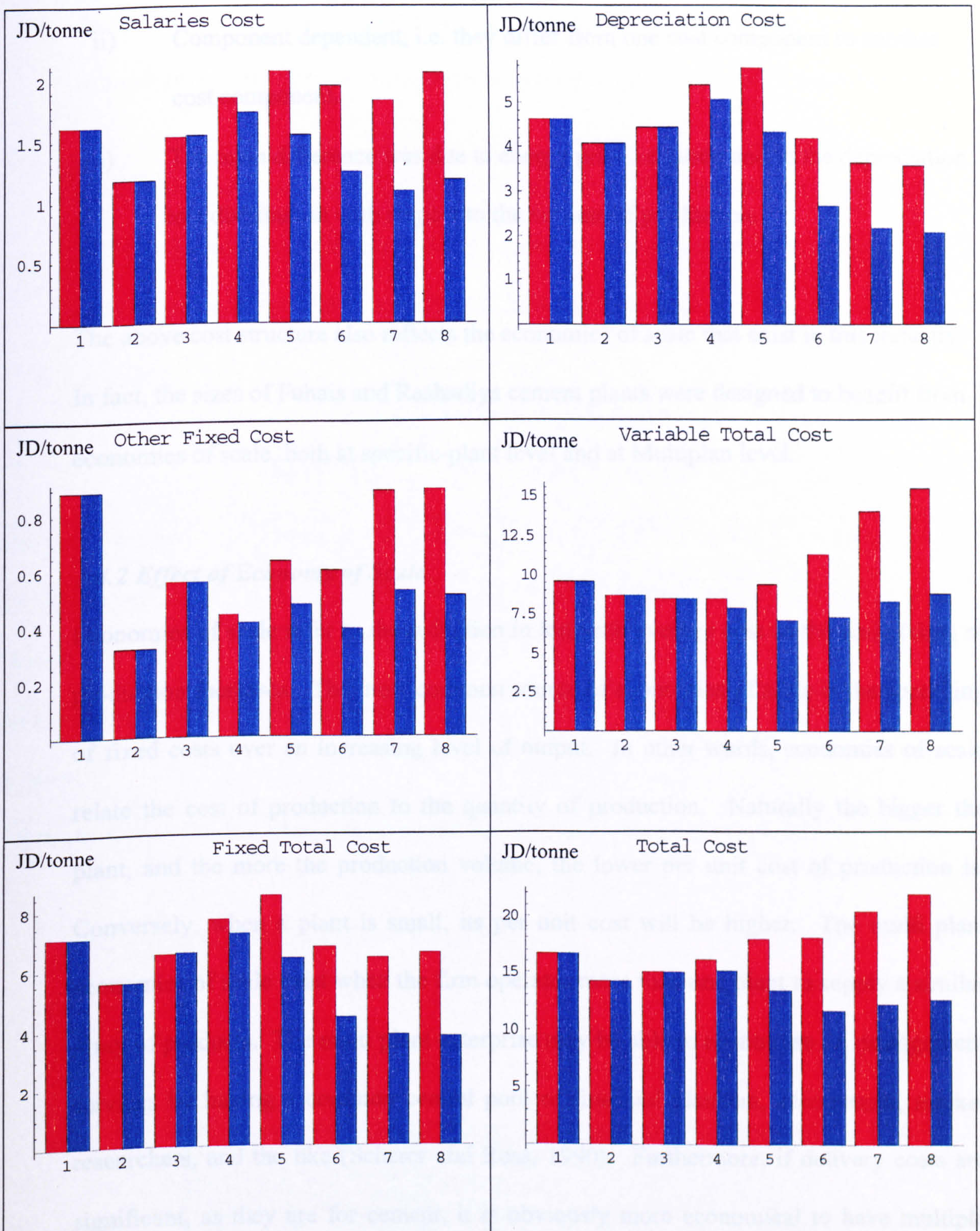


Figure (5.11) confirms the above conclusions, namely that the differences between the raw data and the inflation-adjusted data are:

i) Negligible before 1989 on all cost components, but they start increasing after that

ii) Component dependent, i.e. they differ from one cost component to another cost component.

iii) The main difference was due to energy price variation and to the depreciation cost distribution with respect to the volume of production.

The above cost structure also reflects the economies of scale that exist in this industry. In fact, the sizes of Fuhais and Rashadiya cement plants were designed to benefit from economies of scale, both at specific-plant level and at Multiplan level.

5.4.2 Effect of Economy of Scale

Economies of scale refer to the reduction in long-run average cost as the scale (size) of production increases. The most common source of economies of scale is the spreading of fixed costs over an increasing level of output. In other words, economies of scale relate the cost of production to the quantity of production. Naturally the bigger the plant, and the more the production volume, the lower per unit cost of production is. Conversely, when a plant is small, its per unit cost will be higher. The multi plant economies of scale exist when the firm operates more than one plant to supply a similar array of products. The multi plant enterprise may be able to economise on management services by having a common central pool of financial planners, accountants, market researchers, and the like (Scherer and Ross, 1990). Furthermore, if delivery costs are significant, as they are for cement, it is obviously more economical to have multiple plants to serve the same market. The fixed cost of management is then spread over large number of units.

Building large plants to benefit from economies of scale assumes that those plants will operate at approximately full capacity such that the fixed costs (managerial, depreciation, etc.) are dispersed over larger quantities. However, if production volume is much below capacity, the average fixed (and hence average total) costs will be high.

This concept is explained by table (5.6) fixed unit cost (on current terms) pertinent to JCF (Rashadiya plant). Figure (5.12) presents this raw data in red bars together with the corresponding adjusted data according to inflation rates in blue.

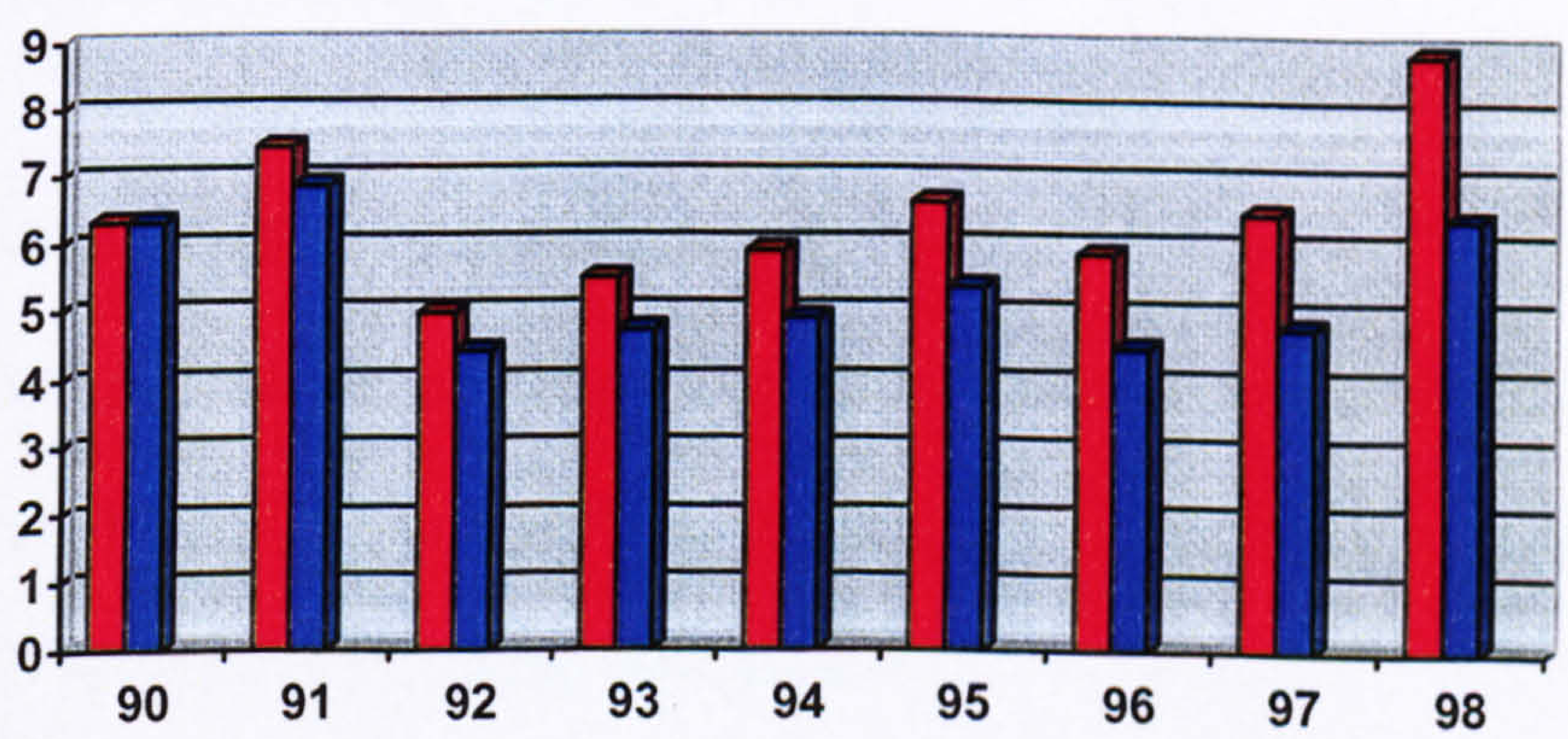
Table (5.6) Fixed unit cost

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Production (10^6 tonnes)	0.546	0.403	1.063	1.562	1.571	1.503	1.952	1.882	1.382
Current Unit Fixed Cost (J.D/tonnes)	6.318	7.437	4.965	5.484	5.890	6.610	5.848	6.445	8.871
Adjusted Unit Fixed Cost (J.D/tonnes)	6.318	6.87	4.42	4.72	4.89	5.37	4.46	4.77	6.37

Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

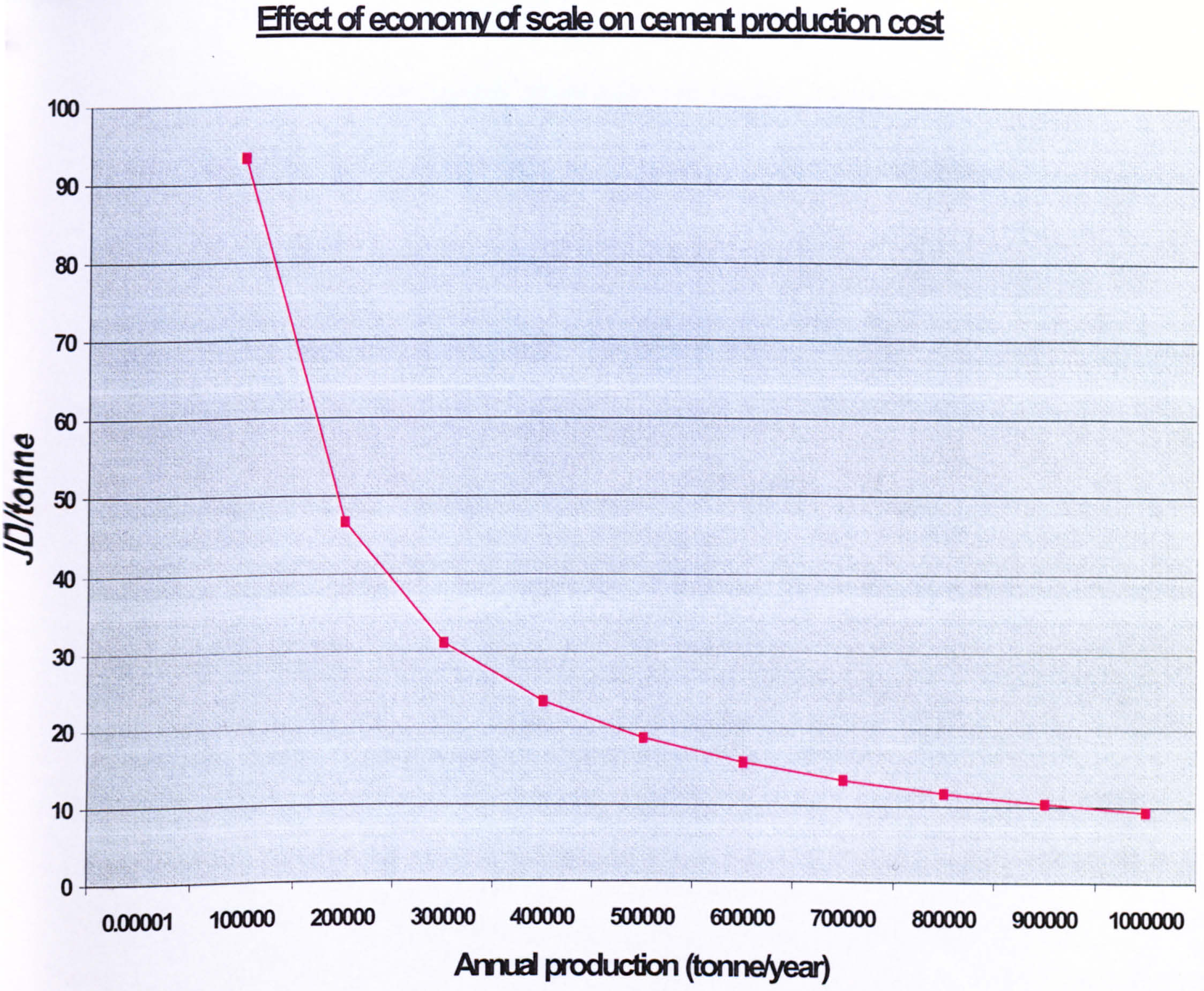
Figure (5.12): Bar chart of unit fixed cost

JD/tonne



9 years between 1990-1998

This information included in table 5.6, with minor deviations due to price escalations, demonstrates in a clear manner the effect of economies of scale on fixed cost. To elaborate more about the effect of economies of scale and to avoid any ambiguity because of different accounting polices, we will discuss the effect of economies of scale on a one million ton cement production line. According to the current international prices, the cost for such a line will be around JD140 million. If we adopt a straight line depreciation policy over 15 years period, the annual fixed cost per tonne of cement (taking into consideration the major element of this cost which is the depreciation and ignoring other elements for simplification) will vary in accordance with the level of production, from zero capacity utilisation to the maximum load in accordance with the following figure:



Notice, again, that the economies of scale can be achieved if the plants are used at nearly full capacity, which will reduce the unit cost to minimum. Otherwise, fixed and average costs will be very high.

5.4.3 Sources Of Energy Cost Variation

Table (5.7) presents the current per unit cost of electricity and fuel for clinker as well as cement production at Fuhais and Rashadiya plants. It can be seen from this table that there is a variation in the energy per unit cost during the period (1985-1992). This is due to three main reasons. First, the increase in energy prices. Second, the operation of older kilns dictated by demand, consumes more energy. Third, the absence of energy management system, because introducing such a system will result in more energy efficient operation consistently.

Table (5.8) presents the costs of electricity and fuel (after adjusting for inflation). The following analysis will use the data available in table 5.7 and 5.8.

Table (5.7)
Electrical and Fuel Consumption Current Cost

Fuhais Plant		JD/ Ton		
Year	**Product**	**Electricity**	**Fuel**	**Total**
1985	CLINKER	1.605	4.254	5.859
1986	"	1.250	4.122	5.372
1987	"	1.184	4.170	5.354
1988	"	0.974	4.137	5.111
1989	"	0.891	4.118	5.009
1990	"	1.425	4.770	6.195
1991	"	2.294	5.893	8.187
1992	"	2.601	6.166	8.767
1985	CEMENT	2.516	3.518	6.034
1986	"	2.135	3.256	5.391
1987	"	1.891	3.165	5.056
1988	"	1.696	3.194	4.890
1989	"	1.598	3.171	4.769
1990	"	2.358	3.806	6.164
1991	"	3.764	4.808	8.572
1992	"	4.110	5.038	9.148
Rashadiya Plant				
1985	CLINKER	1.561	4.467	6.028
1986	"	1.279	4.382	5.661
1987	"	0.959	4.362	5.321
1988	"	1.101	4.375	5.476
1989	"	1.001	4.292	5.293
1990	"	1.278	4.827	6.105
1991	"	1.974	5.639	7.613
1992	"	2.021	5.723	7.744
1985	CEMENT	3.025	4.248	7.273
1986	"	2.622	4.128	6.750
1987	"	1.916	4.061	5.977
1988	"	2.185	4.082	6.267
1989	"	1.972	4.069	6.041
1990	"	2.551	4.542	7.093
1991	"	4.074	5.312	9.386
1992	"	3.893	5.483	9.376

Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

Table (5.8)
Electrical and Fuel Consumption Adjusted Costs

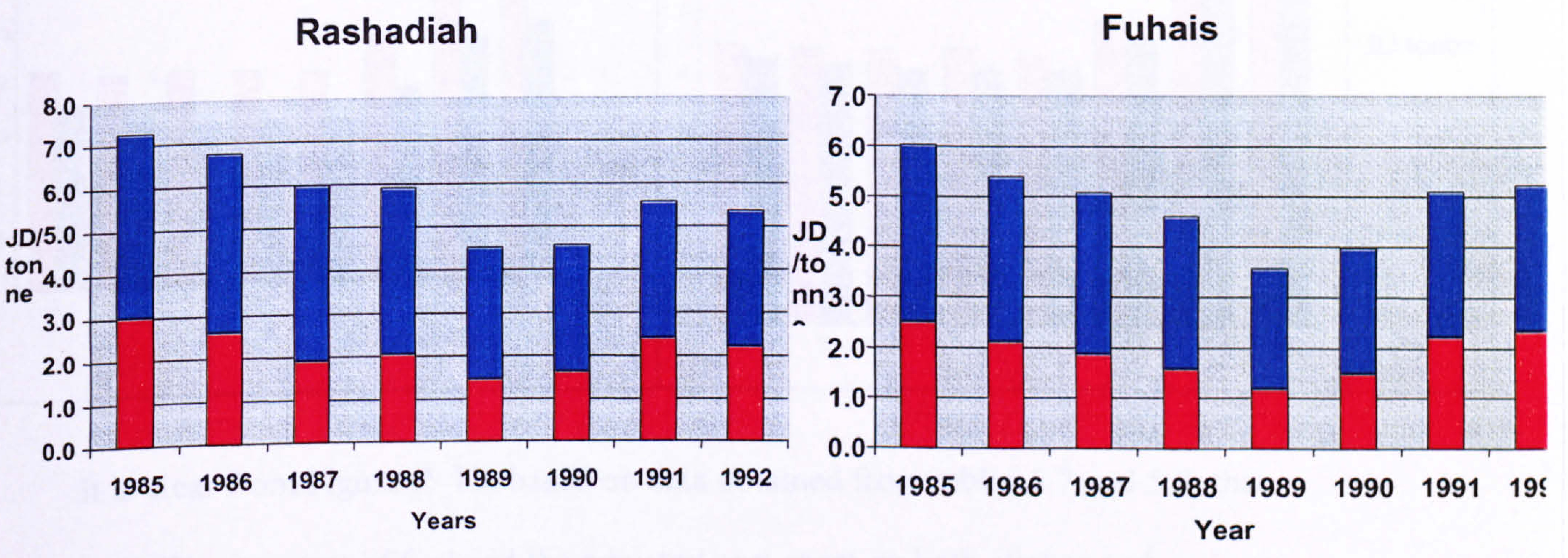
Fuhais Plant		JD/ Ton		
Year	Product	Electricity	Fuel	Total
1985	CLINKER	1.605	4.254	5.859
1986	"	1.25	4.122	5.372
1987	"	1.1863727	4.17836	5.364729
1988	"	0.9188679	3.90283	4.821698
1989	"	0.666218	3.07911	3.745327
1990	"	0.9168704	3.0691	3.985973
1991	"	1.3640147	3.50398	4.867999
1992	"	1.4877309	3.52685	5.014586
1985	CEMENT	2.516	3.518	6.034
1986	"	2.135	3.256	5.391
1987	"	1.8947896	3.17134	5.066132
1988	"	1.6	3.01321	4.613208
1989	"	1.1948557	2.37102	3.565874
1990	"	1.5171793	2.44885	3.966028
1991	"	2.2380782	2.85884	5.09692
1992	"	2.3508551	2.88166	5.232512
Rashadiya Plant				
1985	CLINKER	1.561	4.467	6.028
1986	"	1.279	4.382	5.661
1987	"	0.9609218	4.37074	5.331663
1988	"	1.0386792	4.12736	5.166038
1989	"	0.7484672	3.20921	3.957679
1990	"	0.822288	3.10578	3.928066
1991	"	1.1737424	3.35296	4.526698
1992	"	1.1559801	3.27347	4.429446
1985	CEMENT	3.025	4.248	7.273
1986	"	2.622	4.128	6.75
1987	"	1.9198397	4.06914	5.988978
1988	"	2.0613208	3.85094	5.912264
1989	"	1.4745028	3.04247	4.516973
1990	"	1.6413589	2.9224	4.563763
1991	"	2.4224046	3.15852	5.580925
1992	"	2.2267345	3.13619	5.362924

Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

Based on the data in tables 5.7 and 5.8, Figure (5.13) provides stacked bar charts for the energy costs for cement (based on adjusted data) in the two plants ordered from bottom to top as follows; Red for electricity, Blue for fuel. It is clear that both plants have an almost similar pattern. However, the energy cost per tonne of cement in Fuhais plant is lower than that in Rashadiya plant in some cases. The reason for this is that in Fuhais they add pozzolana (which is a volcanic material with cements properties, need not to be burned in the kiln) with around 20% to the clinker in each tonne of cement. The addition of this material will save the fuel and electrical energy needed to produce equivalent quantity of the added material of clinker.

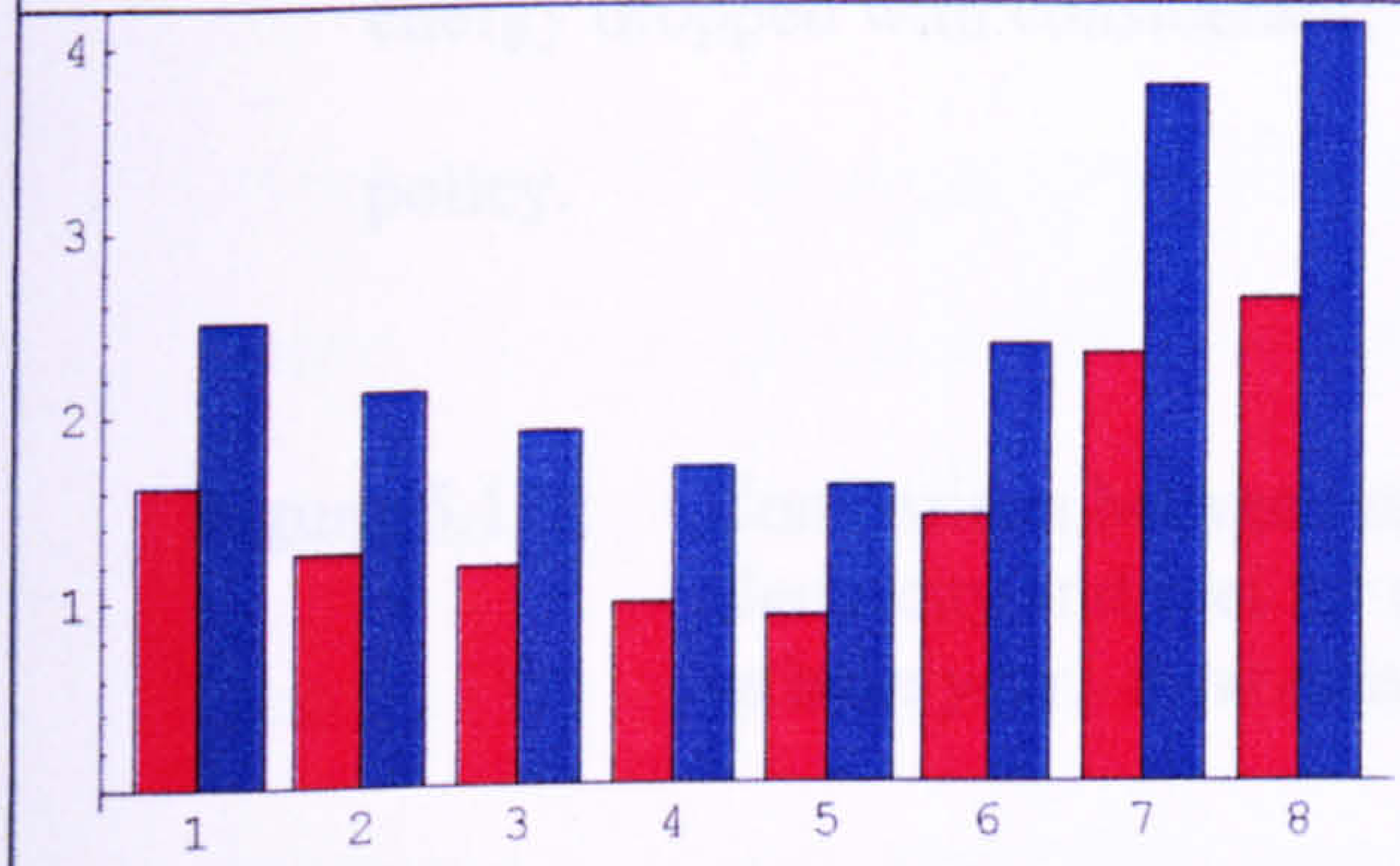
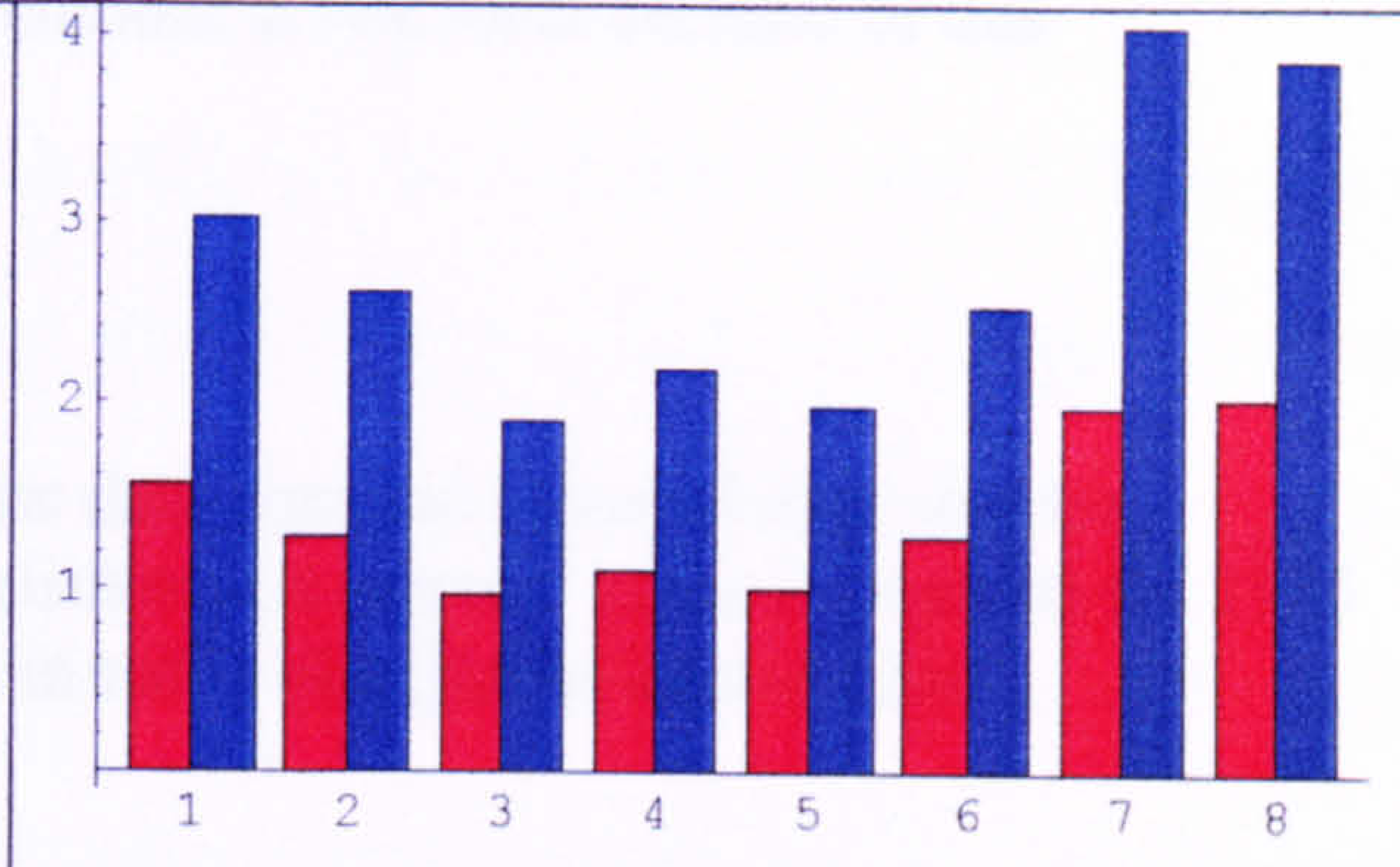
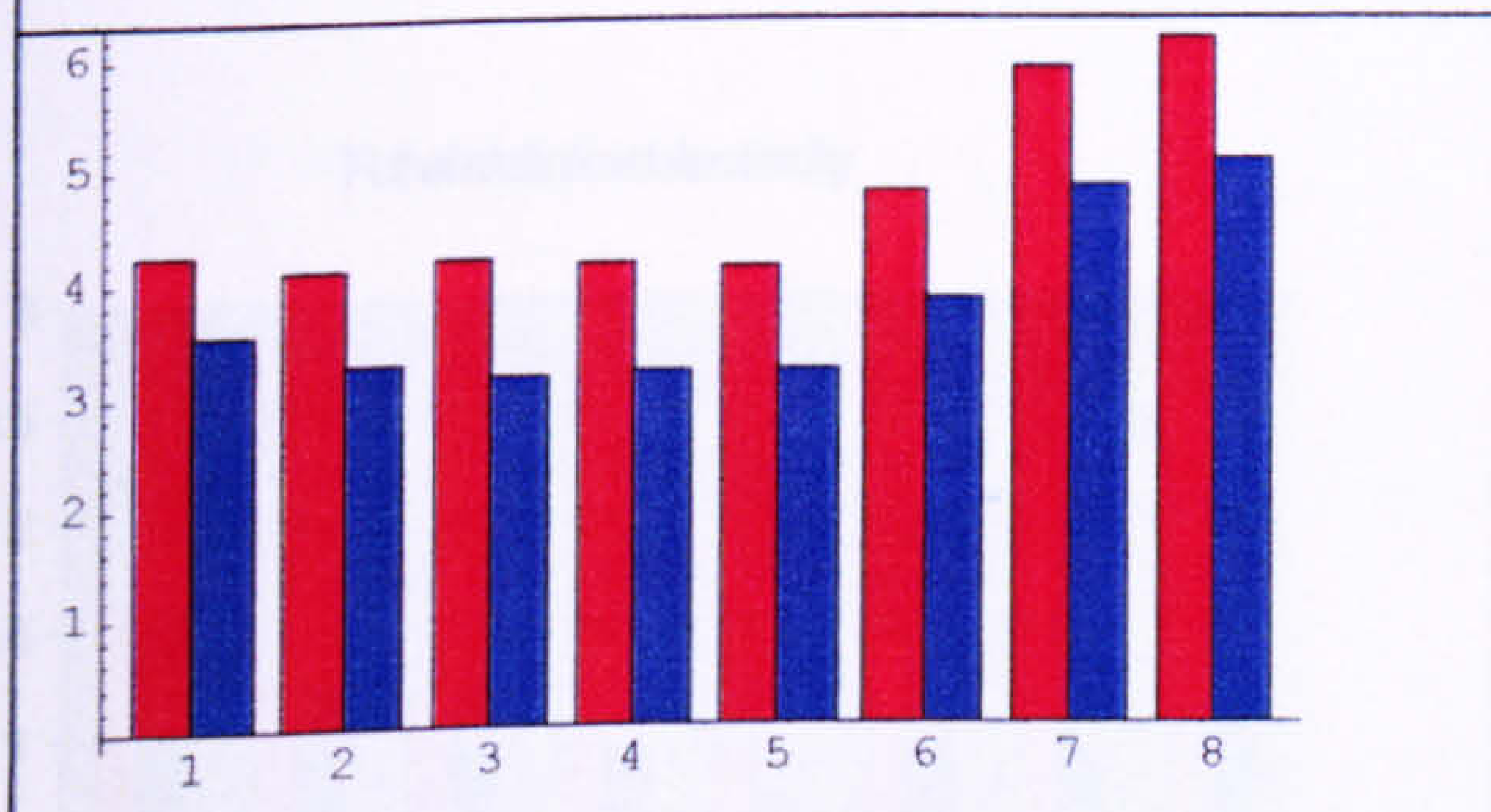
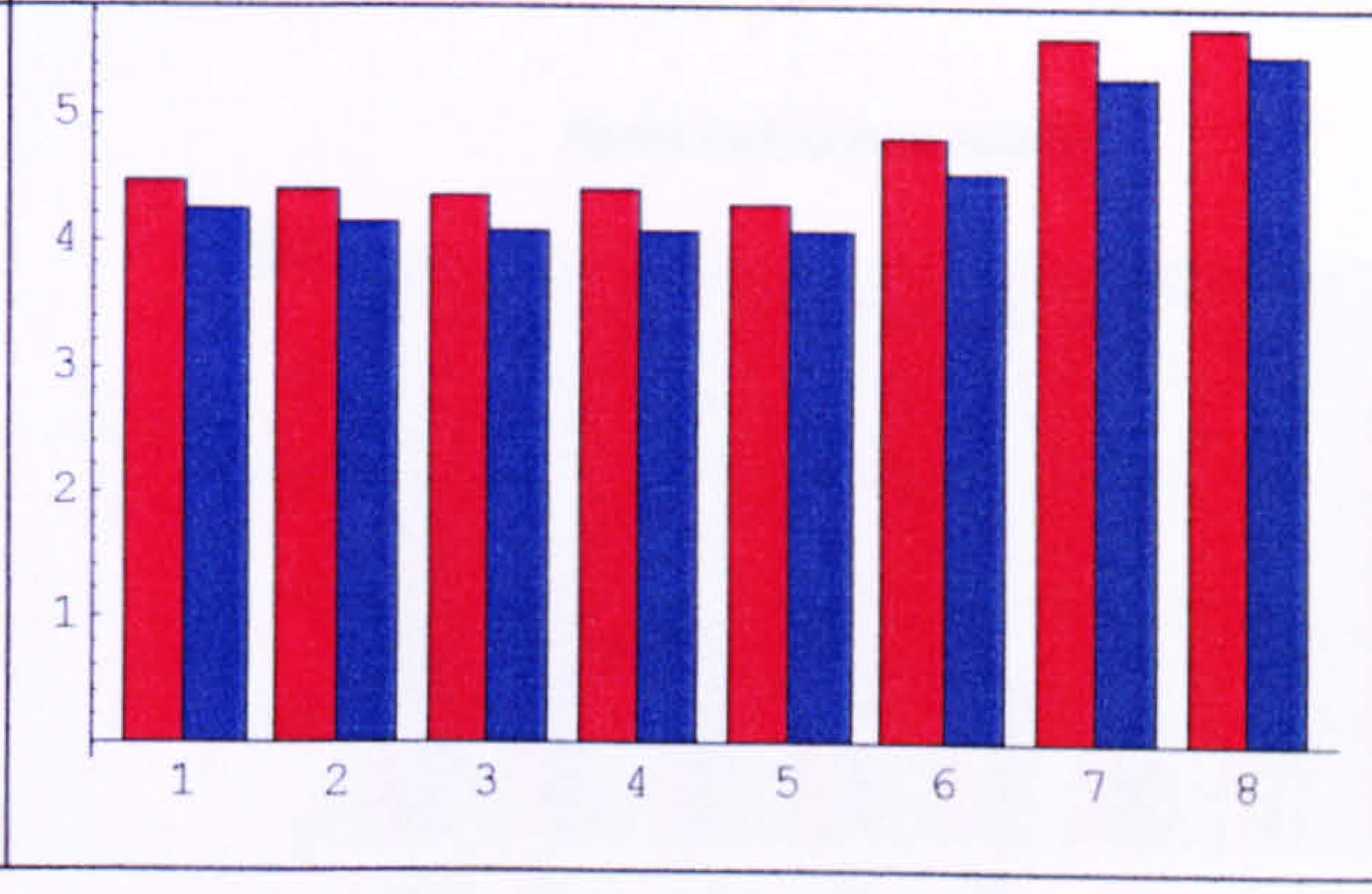
Figure (5.13): Comparison of Energy Cost for cement in the Two Plants

Electricity in Red, Fuel in Blue



Based on the data in tables 5.7 and 5.8, Figure (5.14) gives bar charts of the energy cost of clinker in red and cement in blue for both plants. It is clear that the differences of fuel costs between cement and clinker are very small compared to the corresponding costs of electricity. Moreover, the structures of the two plants are almost the same except that the differences of fuel cost in Rashadiya plant are much smaller than those in Fuhais plant.

Figure(5.14):Comparison between energy cost of clinker and cement (red for clinker and blue for cement)

Fuhais Plant	**Rashadiya Plant**	**Cost for**
		El JD/tonne
		Fuel JD/tonne

It is clear from Figure (5.15) based on data obtained from tables 5.7 and 5.8, that:

a) The raw cost of fuel and the adjusted cost spent on both clinker and cement is almost the same for the years 1985-1989 but they differ for the last three years, namely, 1990-1992. This is mainly due to the financial crisis in Jordan that resulted in the devaluation of the Jordanian currency by around 50%, as explained earlier. According to an emergency program, recommended by the International Monetary Fund (IMF) to alleviate the country's economic problems, Jordan gradually reduced all subsidies, including energy subsidy, which resulted in higher inflation rates in the years 1990-1992.

b) As a consequence, the differences between energy costs computed from raw data and adjusted data were very high for last two years. This was because of the high inflation in these years, and this reflect the government policy which is still subsidies the energy prices so that the real cost of energy dropped with considerable amount in real term because of this policy.

Figure(5.15): Comparison between raw data cost and adjusted data cost for electricity and fuel for clinker and cement in the two plants for 1985 as base year. Raw data in red, and adjusted data in blue.

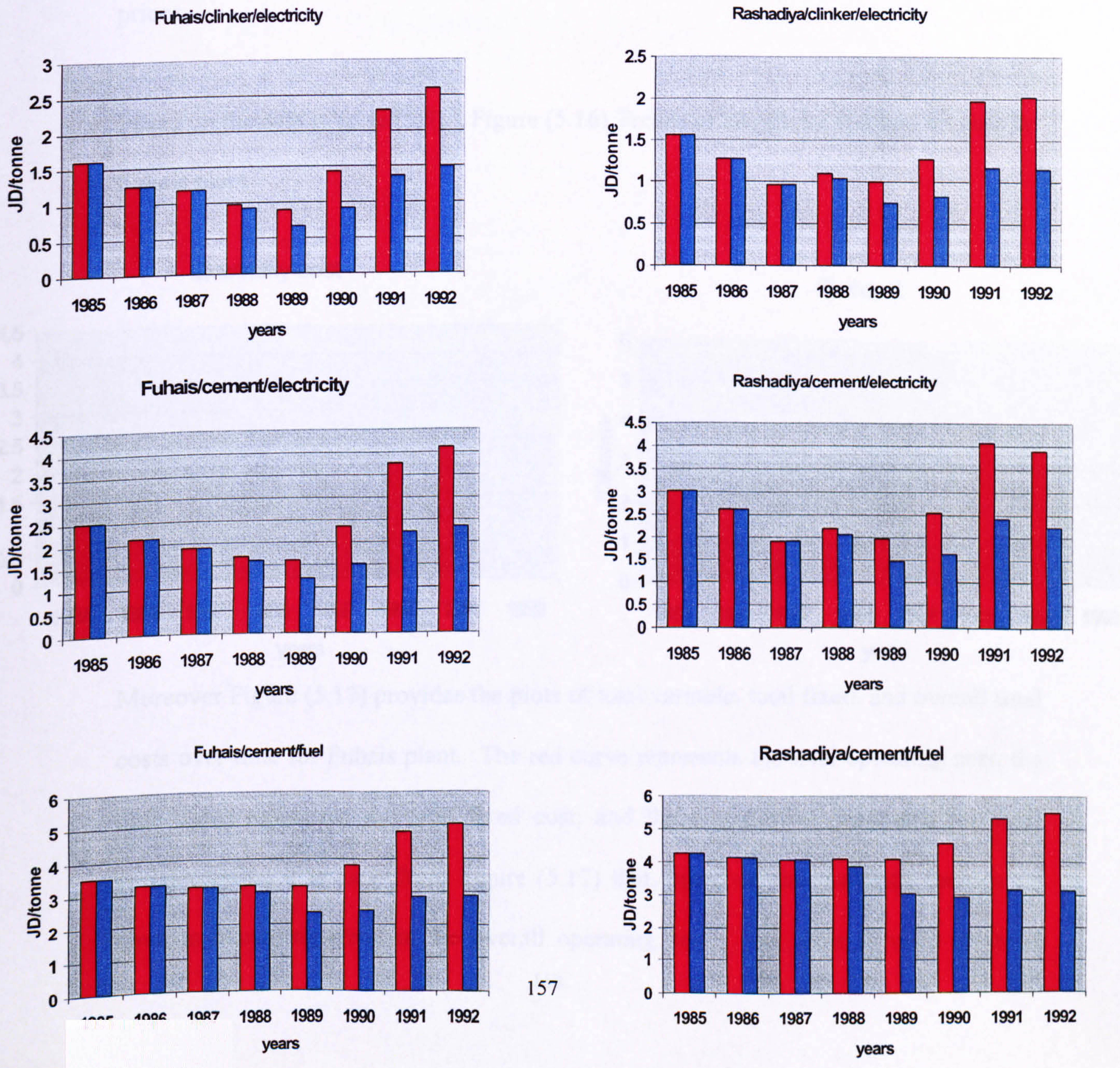
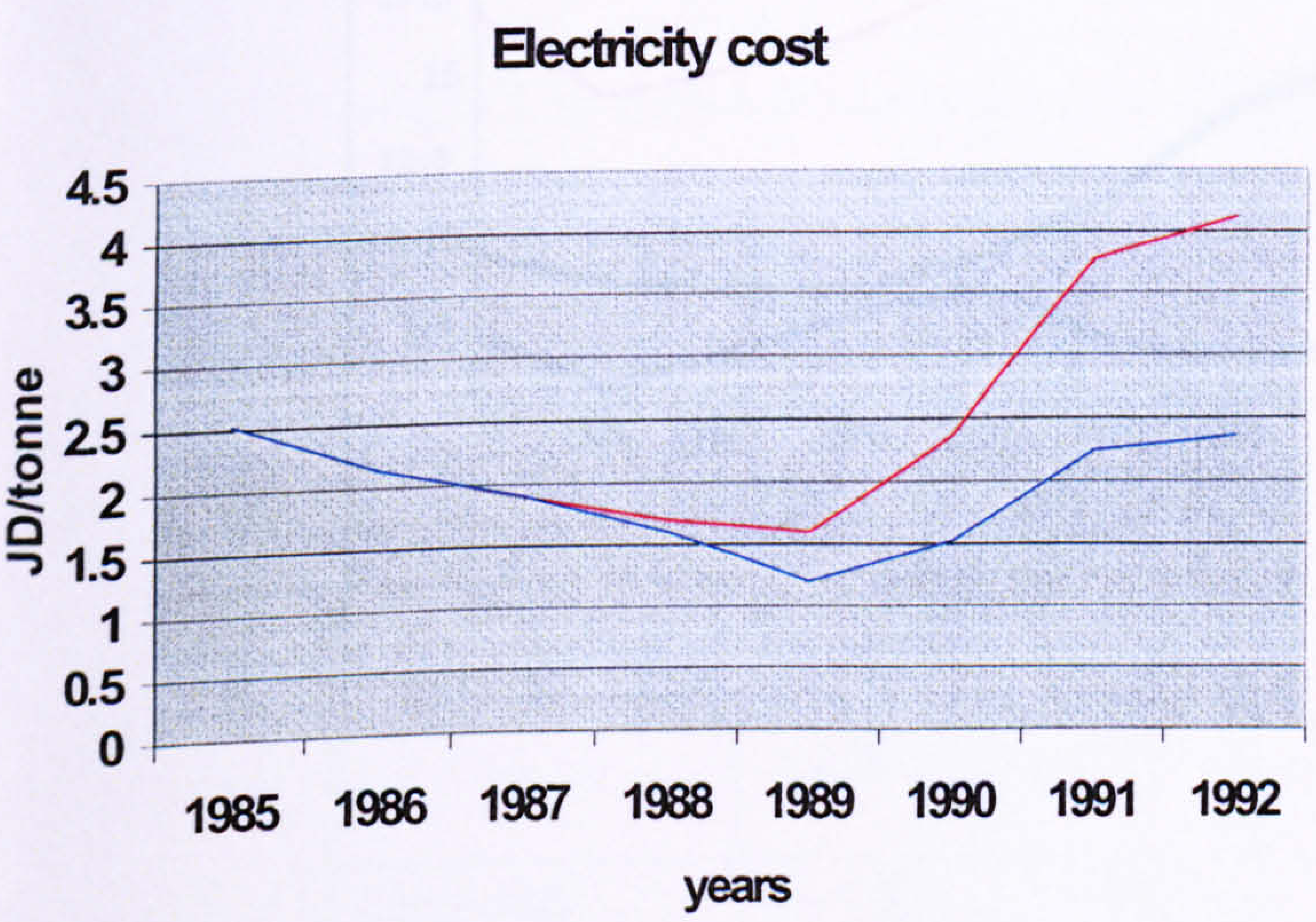
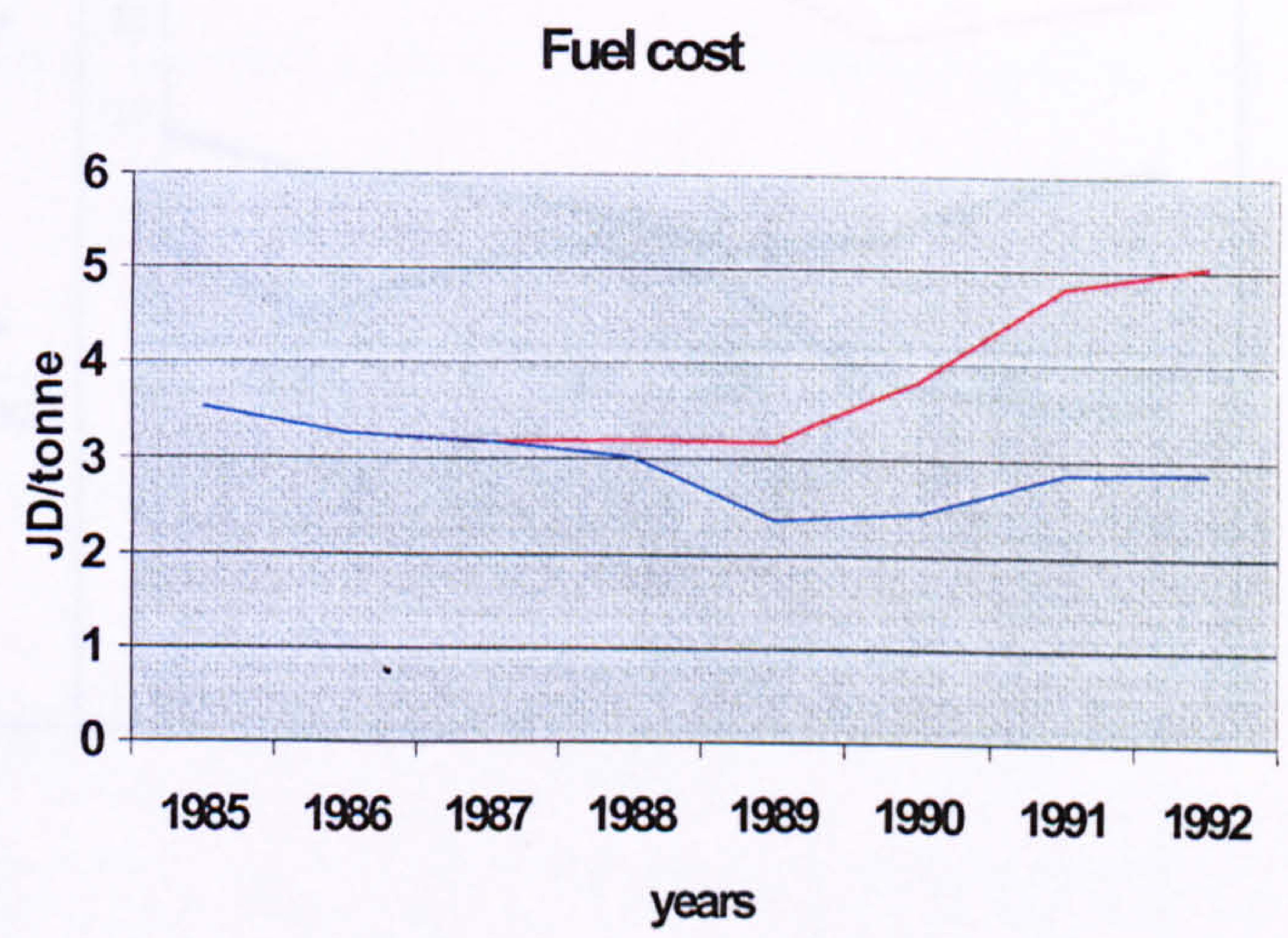


Figure (5.16) also shows the trends in fuel and electricity cost per tonne of cement produced for the period 1985-1992 in Fuhais plant. Note that the red plot is for the raw data and the blue one is for inflation adjusted data. It is clear that there was a decreasing trend up to the year 1989 then an increasing trend after that. As we mentioned before and due to the economic restructuring program after the devaluation of the Jordanian Dinar by about 50%, the inflation figure increased during the last three years. The energy prices and the current energy cost increased, while in real terms and based on 1985 prices, the energy cost decreased compared with the current cost of energy. The increasing trend of the energy cost (in current and real terms) reflects the government restructuring policy, which tries to minimise the subsidy on the energy prices.

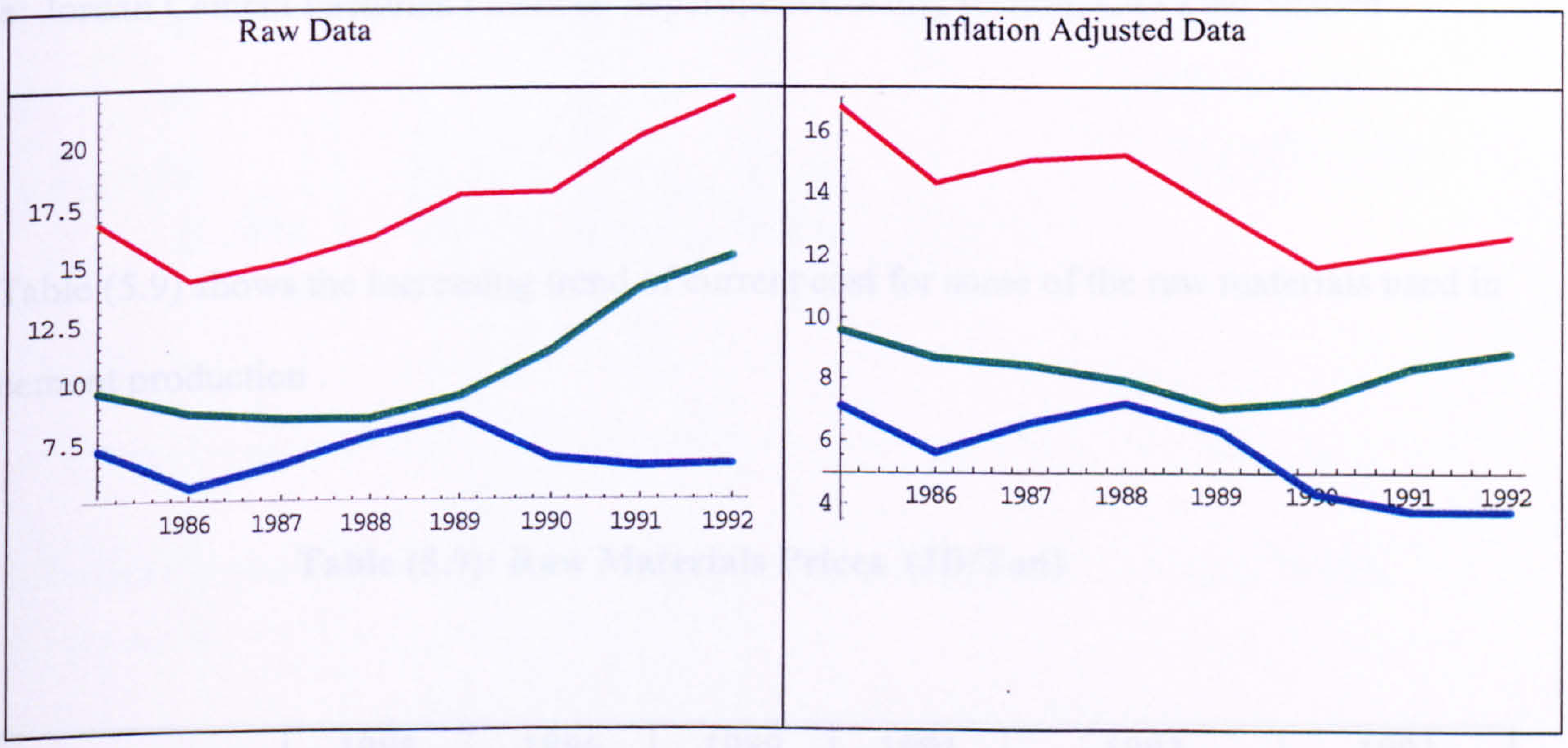
Based on the data in table (5.5) , Figure (5.16) Trends of electricity and fuel oil cost in Fuhais plant





Moreover Figure (5.17) provides the plots of total variable, total fixed, and overall total costs over time for Fuhais plant. The red curve represents the total operating cost, the blue curve represents the total fixed cost, and the green curve represents the total variable cost. It is clear from Figure (5.17) that, based on the raw data, there is an obvious increasing trend in the overall operating cost. The same is valid for total variable cost. However, based on inflation-adjusted data, these trends are decreasing due to the reasons mentioned of the government subsidy policy that does not reflect totally the effect of inflation on the prices of goods and services. Moreover, inspection of figure (5.17) and table (5.5) shows that fixed costs in Fuhais Factory decrease as production level increases which match with the economy of scale concept.

Figure (5.17): Evolution of total costs of production



The previous figures indicate a sharp rise in the current cost of production of cement, despite the fact that production level has increased. This is mainly due to the increase in the costs of electricity and fuel as illustrated in figures (5.18) and also partially due to the increasing trend for some of the raw materials used in cement production as illustrated in table (5.9).

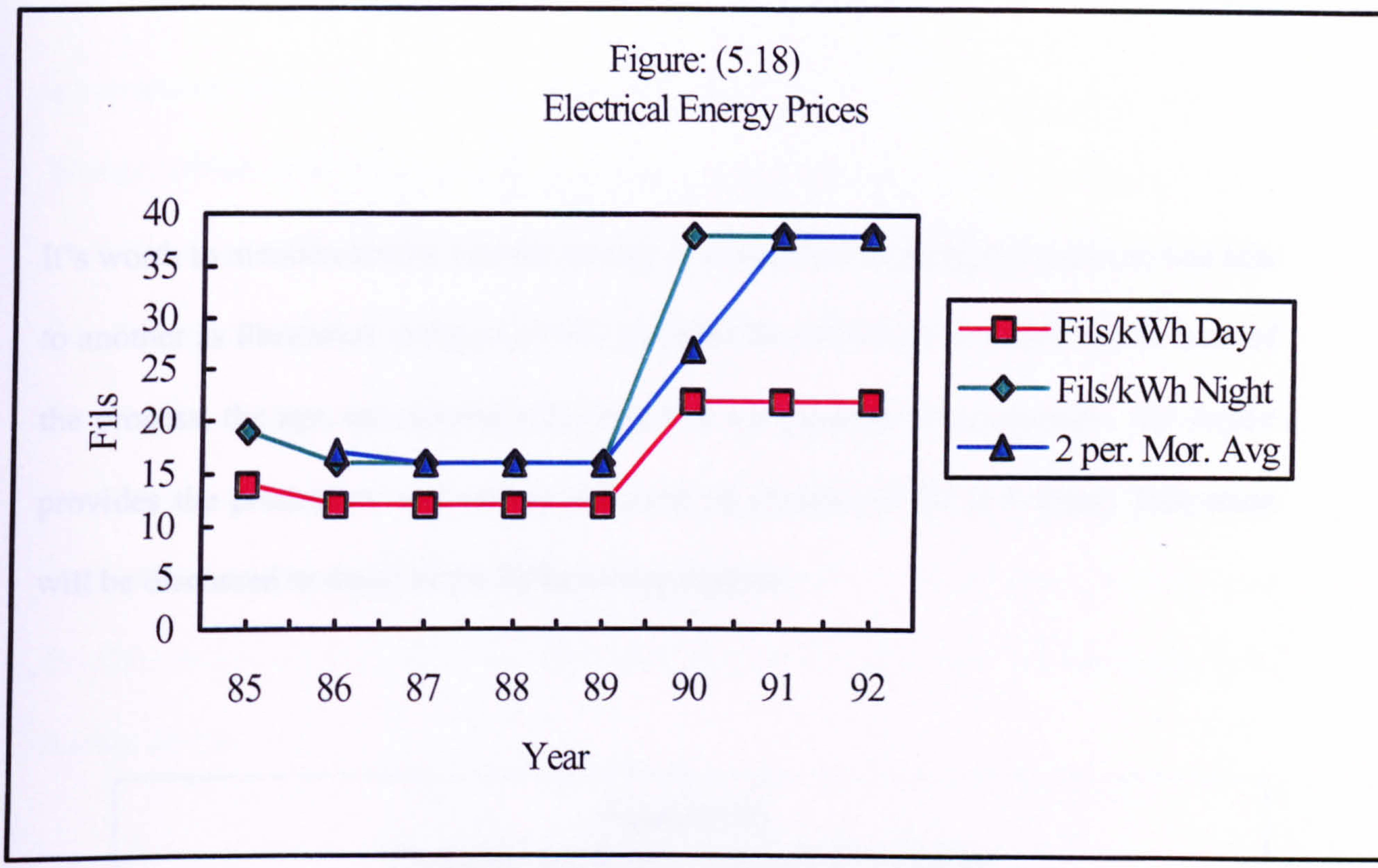


Figure (5.18) shows the historical official prices of electrical energy.

Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

Table (5.9) shows the increasing trend of current cost for some of the raw materials used in cement production .

Table (5.9): Raw Materials Prices (JD/Ton)

	1985	1986	1989	1991	1992	1993
Gypsum	4.8	5.1	4.5	4.5	7.1	7.75
Pozzolana	2.8	2.7	2.7	3.3	3.9	4.375
Sand	0.7	0.48	0.42	0.56	1.1	1.15

Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

It's worth to mention briefly that the energy consumption level differs between one kiln to another as illustrated in figure (5.19). Usually this difference depends on the type of the process, the age, operational efficiency and the capacity of production. The figure provides the production and energy unit cost of production for JCF kilns. This issue will be discussed in detail in the forthcoming chapters.

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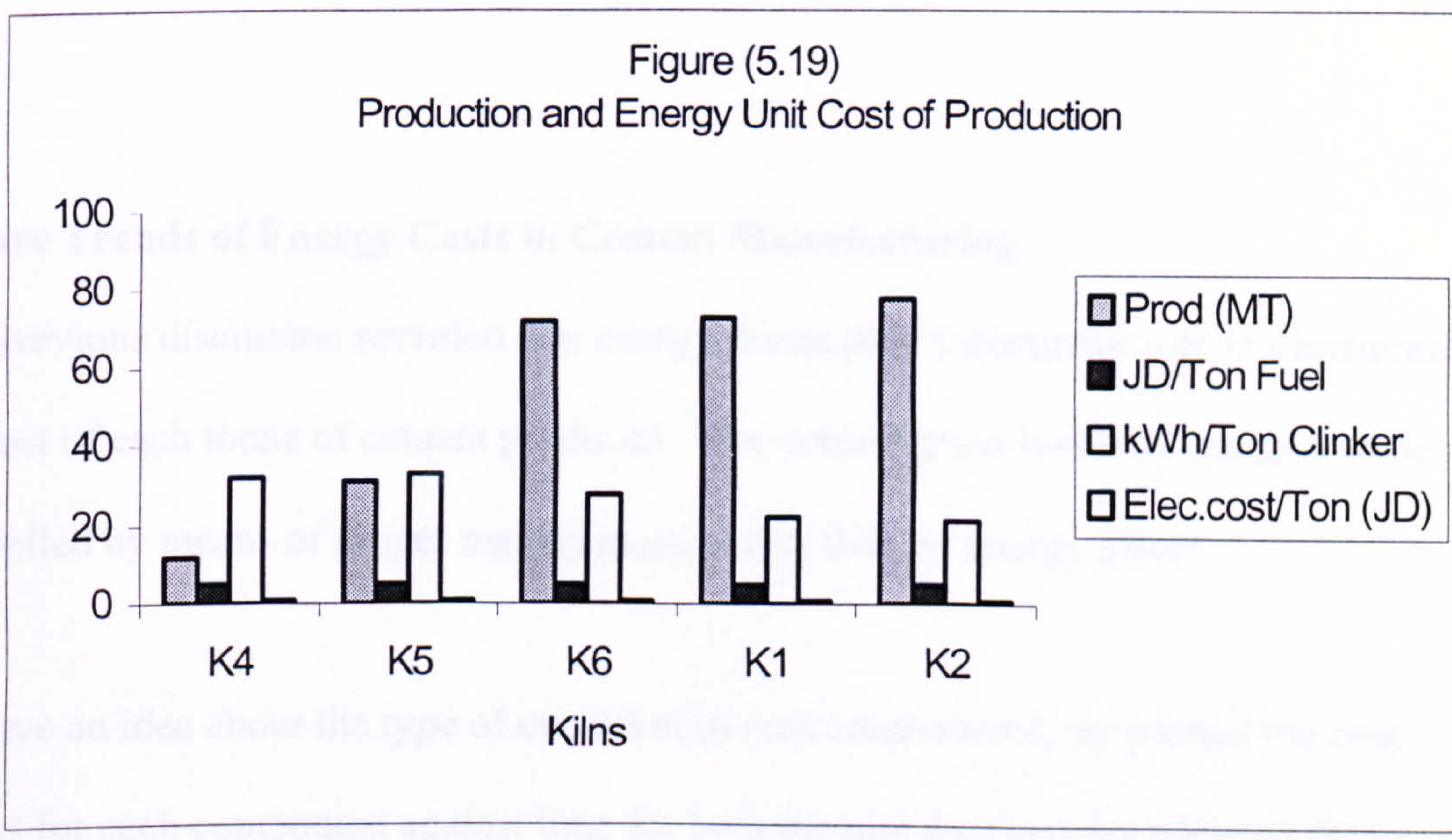


Source: Jordan Cement Factories Financial department/Costing section, C/O Ziad Shadeh

It is important to realise that the variation of the prices of electricity and fuel is beyond the control of the management of the cement factory. Similarly, the doubling of prices of cement bags and raw materials over the same time-span 1985-1992 is also outside the control domain of the management.

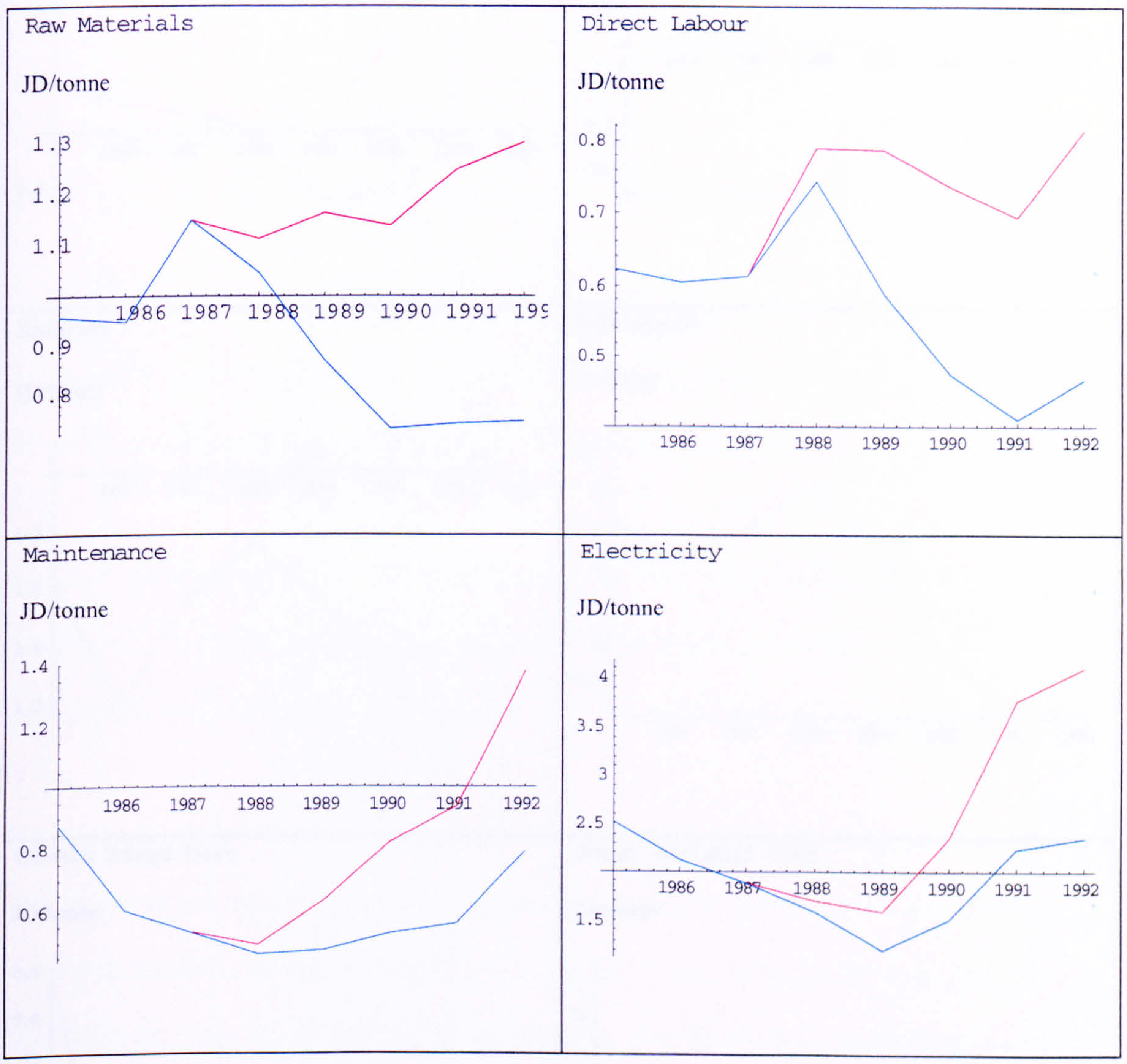
In Jordan, as in other developing countries, the price level and, hence the inflation rate, is not a result of the free play of the market mechanism but, rather, is the result of government interventions in the market place. This is evident from the prices of energy, which remain constant for a period of time (irrespective of international prices variation) and then suddenly increase. However, the purpose of the research work in this chapter is not to demonstrate how energy prices are determined but, rather, to show the relative importance of energy (fuel and electricity) cost with respect to overall production cost. In other words the main objective of the energy cost analysis is to show that energy cost is a major portion of the total and variable manufacturing cost. In other words energy prices are administrative i.e. imposed and not determined by market forces.

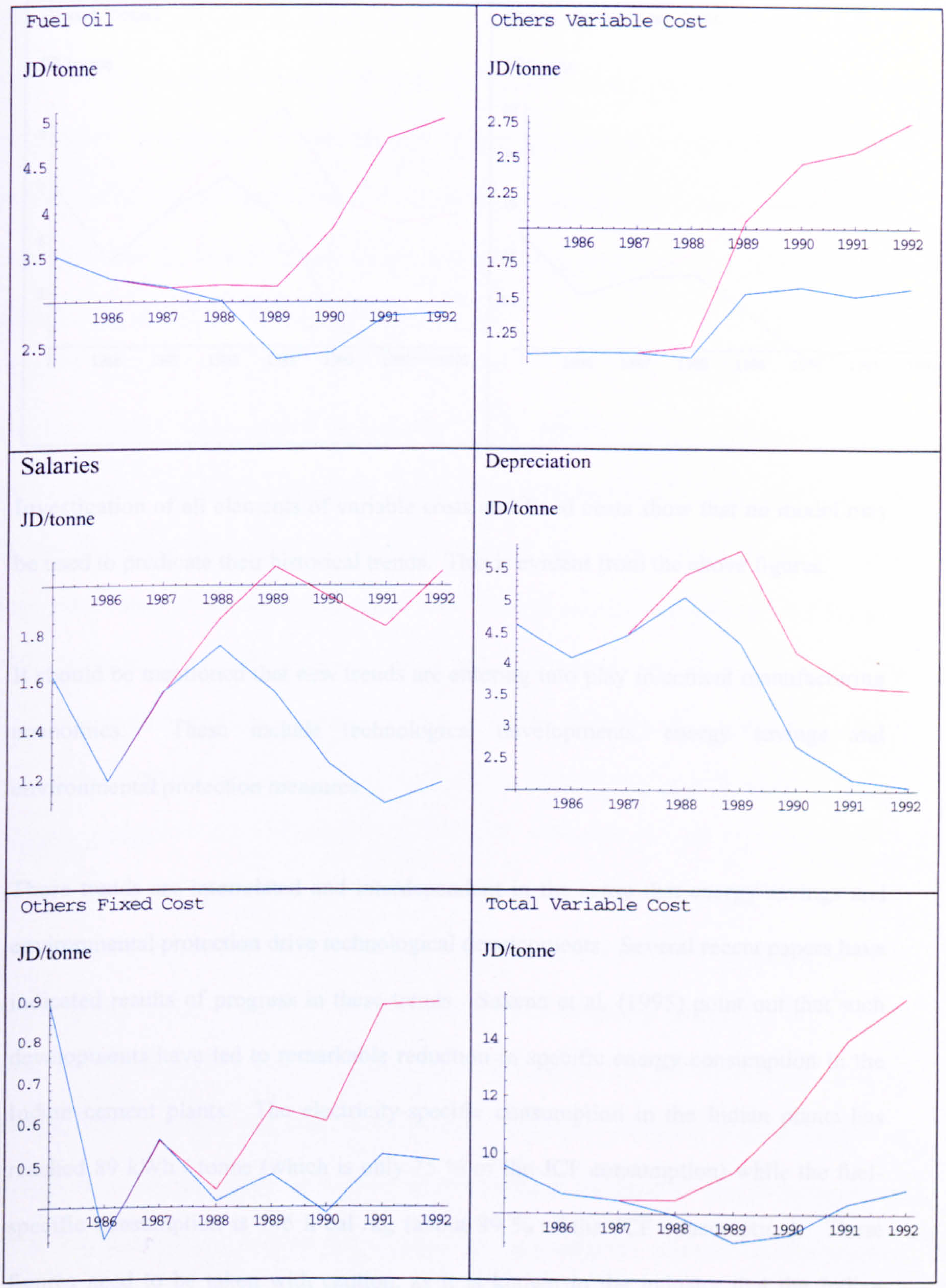
5.5 Future Trends of Energy Costs in Cement Manufacturing

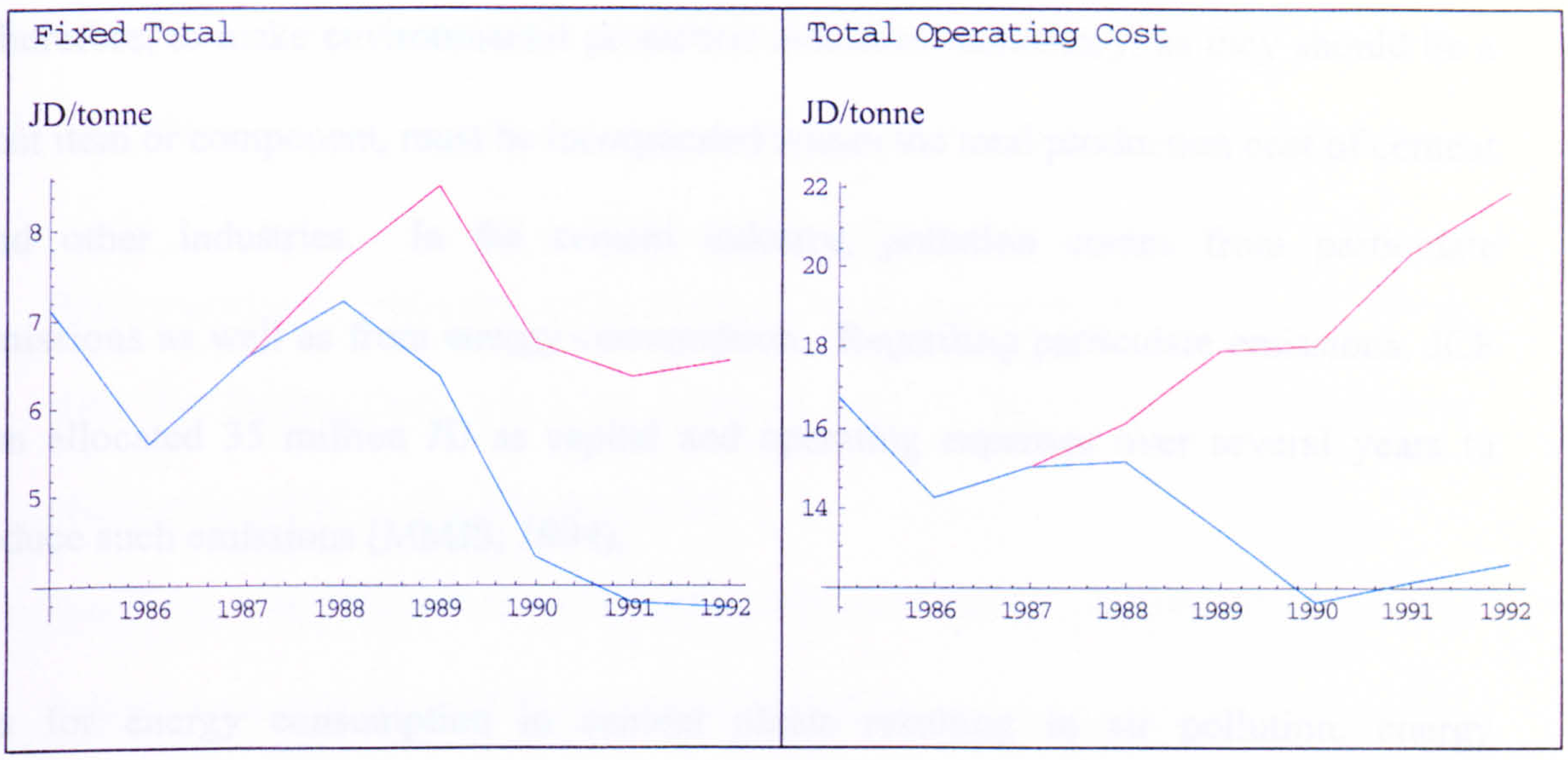
The previous discussion revealed that energy prices play a dominant role in determining the cost of each tonne of cement produced. The consumption levels of energy can be controlled by means of proper management, rather than by energy prices.

To have an idea about the type of evolution of cost components, we plotted the cost values for each component against time for both the raw data and for adjusted data according to inflation rates. The red plots are for raw data, while the blue plots are for adjusted data. The results are given in Figure (5.20) based on data obtained from table (5.5) It is clear from this figure that it is not easy to fit a model for a trend on time. Moreover, the red plot is always higher than the blue one, and the differences between them increase with time.

Figure (5.20): Evolution of Cost Components




Fuel Oil
JD/tonne
5
4.5
4
3.5
2.5
1986 1987 1988 1989 1990 1991 1992
Others Variable Cost
JD/tonne
2.75
2.5
2.25
1.75
1.5
1.25
1986 1987 1988 1989 1990 1991 1992
Salaries
JD/tonne
1986 1987 1988 1989 1990 1991 1992
1.8
1.6
1.4
1.2
Depreciation
JD/tonne
5.5
5
4.5
4
3.5
3
2.5
1986 1987 1988 1989 1990 1991 1992
Others Fixed Cost
JD/tonne
0.9
0.8
0.7
0.6
0.5
1986 1987 1988 1989 1990 1991 1992
Total Variable Cost
JD/tonne
14
12
10
1986 1987 1988 1989 1990 1991 1992



Investigation of all elements of variable costs and fixed costs show that no model may be used to predicate their historical trends. This is evident from the above figures.

It should be mentioned that new trends are entering into play in cement manufacturing economics. These include technological developments, energy savings and environmental protection measures.

These trends are interrelated and interdependent in the sense that energy savings and environmental protection drive technological developments. Several recent papers have indicated results of progress in these trends. Saxena et al. (1995) point out that such developments have led to remarkable reduction in specific energy consumption in the Indian cement plants. The electricity-specific consumption in the Indian plants has reached 89 kWh / tonne (which is only 75 % of the JCF consumption) while the fuel-specific consumption is 746 k cal /kg (about 89 % of the JCF consumption). These figures need to be taken with caution, as it is known in the industry that the Indian cement industry is dependent on manual labour and still uses old technology.

As for environmental protection, any measure must be associated with a price tag. Therefore, to make environmental protection measures mandatory, as they should be a cost item or component, must be incorporated within the total production cost of cement and other industries. In the cement industry, pollution comes from particulate emissions as well as from energy consumption. Regarding particulate emissions, JCF has allocated 35 million JD as capital and operating expenses over several years to reduce such emissions (MMIS, 1994).

As for energy consumption in cement plants resulting in air pollution, energy management, including auditing and conservation, will help achieve the objective of the World Energy Congress that the full cost pricing of energy should reflect the long-term marginal costs of increasing supplies, and should ideally incorporate the costs of environmental detriments where these are not captured by market mechanisms. The Congress points out that appropriate signals from the end-user of energy are needed to induce the political and the business decision - taking necessary for desired change (Khatib, 1996).

Moreover, other scholars such as Bakken and Lucas (1996) argue that the inclusion of the monetary values of environmental externalities in electricity prices will be the main issue for future energy policy. Environmental externalities are defined as costs to society, human health and other environmental damages, resulting from provision of electric services, which are not already incorporated in the price of electricity services. They are those costs, which occur after all government- imposed environmental standards and regulations are met (PACE, 1991).

Concerning forecasting future costs, the 1992 prices for all elements of variable costs, as well as fixed costs, are not likely to remain the same or decrease for many reasons, which include:

- Energy prices are managed and subsidised by the government. Jordan has agreed with the International Monetary Fund as part of the economic restructuring program to remove subsidies gradually.
- Quarrying and transport of raw materials consume energy, and the prices of these materials are sensitive to fuel and electricity prices.
- Labour cost is on the rise. By law, wages cannot be decreased; on the contrary, fringe benefits are steadily increasing.
- There is a monopoly in the cement market in Jordan; the market is restricted exclusively to JCF until the end of 2001 and the prices of cement agreed between the company and the government allow special profit margin for the company. This arrangement restricts the market forces and the competition, which can be beneficial for the consumer. It is a temporary arrangement and the market will be opening at the beginning of 2002 and the cement industry should adapt and adjust itself to work within free market environment.

From the previous discussion, it may be concluded that the variable costs and fixed costs of 1992, as shown in table (5.5), are the minimum prices for the future.

5.6 Conclusions

It is clear from the previous analysis that the production cost of cement is affected by several elements, which include: type of process used, energy, availability of raw materials and the management system adopted by the company.

Cement industry is considered an energy intensive industry. It is revealed from the analysis that the energy is the most important cost element, as more than 50 percent of the variable costs are for energy. However, the heavy use of a number of energy sources, (fuel oil, electricity, diesel) poses environmental challenges to cement producers and adds considerably to operating costs.

The high cost of energy in Jordan, coupled with the fact that cement industry in itself, is energy intensive, constitute a strong motive to closely monitor energy costing. Since its introduction at JCF, the energy costing system has provided valuable cost indicators and has helped in the decision making process. This system is used in highlighting the weight of electricity and fuel costs compared to total variable cost or total production cost in order to demonstrate the importance of concentrating on reducing energy consumption.

Economy of scale concept is playing an important role in deciding the total cost of cement. The most common source of economies of scale is the spreading of fixed costs over an increasing level of output. In other words, economies of scale relate the cost of production to the quantity of production. Naturally the bigger the plant (and the more the production volume) the lower per unit cost of production. Conversely, when a plant is small, its per unit cost will be higher.

It is worth mentioning that energy costing analysis for the cement industry is an essential step in evaluating the cost-effectiveness of energy management. Therefore, this chapter is presented before other chapters dealing with detailed energy management aspects, to demonstrate the importance and validity of the subsequent research efforts.

Moreover, the analysis of the production cost elements and the future trends of energy cost and prices gives a platform for the statistical and economic models (which will be discussed in chapter 7).

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Chapter Six

Practical Energy Management

Experience of Cement Industry in Jordan

6.1 Introduction

As we found out from chapter five, electrical and thermal energy are considered major and most important cost items in the overall cost of cement production, where the average cost of consumed energy is around 60-65% of the variable cost and 30-35% of total cost of the produced cement. This fact justifies the importance of concentrating on energy management and conservation so as to reduce consumption as much as possible, in order to reduce the final production cost.

The Jordan Cement Factories Company has two plants for producing different kinds of cement. The first plant is located in the town of Fuhais, which is 15 km Northwest of Amman, and has a designed production capacity of about two million tons per year, with three operating production lines of different capacities. The other plant is located in Rashadiya, 200 km south of Amman and has a designed annual production capacity of about two million tons, with two identical production lines. Three old production lines in Fuhais Factory were shut down because of their low productivity and high specific consumption rate of thermal energy. They used old systems, which needed great manpower, leading to an increase in the final production cost, which meant that they became economically inefficient.

This chapter investigates the pattern of energy use in the cement industry and shows certain ways and means for reducing energy consumption to the least possible value, by using energy management procedures; reviewing the ways and factors affecting energy consumption; studying the causes of the increase in specific rate of thermal and electrical energy consumption and ways for energy consumption saving in the burning and grinding; and the effect of quality on energy consumption.

Practical cases of energy consumption saving in the different production stages are also reviewed in this chapter. These cases were developed and formulated by the author of the thesis with the participation of the concerned departmental engineers in each of the case studies. Therefore, they represent JCF's personnel and management combined initiatives and efforts and accumulated experience in relation to energy consumption savings. Thus, they form the core and basis on which further systematic and organised measures were justified and institutionalised.

6.2 Cement Manufacturing and Energy Consumption

In order to identify the energy saving and conservation possibilities we need to investigate the details of the cement manufacturing and production processes in this section.

6.2.1 Sequence of Production Process in Cement Manufacturing

As illustrated in Fig 5.7 in chapter five, which represents the cement manufacturing processes, these processes are summarised below:

A <u>Extraction of Raw Materials from the Quarry</u>

Raw materials are extracted from the quarries either by drilling or blasting then transported by dump trucks to the crushers. Usually the production capacity of this stage is higher than that of later stages.

B Raw Materials Crushing

The raw material is crushed in the crushers in order to decrease particle size to about 1000 mm. Then, it is stored in pre-blending beds for homogenising. Since the production capacity of the crushers is higher than that of the following production stages, the operational time of crushers could be controlled according to electrical energy tariff, considering that the other production stages will not be affected by the crushers' stoppages.

C Raw Material Grinding

The raw material is supplied to the raw mill through silos, and is ground to the required fineness (15% retained on 90 micron sieve). The production capacity of this stage is higher than that of the following production stages. The ground raw material is stored in a high storage capacity blending silos so the raw required for continuous operation of the later stage is provided. The operation time of this stage can be controlled within certain limits. This stage is considered as one of the high electrical energy consumption stages.

D Raw Material Burning

The raw meal is supplied to the kilns from the raw meal blending silos, and all necessary physical and chemical operations applied to produce the intermediate material called clinker, which is the essential material in cement manufacturing. This stage is operated continuously, unless a sudden fault occurs. It is a high thermal energy consumption stage, since fuel oil is used in burning.

Gardeik (1982) points out that, like other material transformation processes accomplished at high temperatures, cement clinker burning is highly complex because of the various sub-processes such as heating, calcimining, clinkering and cooling do not take place consecutively, but to some extent proceed simultaneously and influence one another. It is therefore. considered one of the most prominent areas to apply energy management measures.

E Cement Grinding

This is the last stage of the cement manufacturing process. Normally, the production capacity of this stage is higher than the burning stage. The cement mills are supplied with clinker and additive materials according to the type of cement required. After the cement grinding process, the produced cement is stored in high storage capacity silos, so the operation time of this stage can be controlled and programmed without affecting the other production stages within a defined limit. This stage is considered as the highest electrical energy consumption stage in the process.

As Ellerbrock and Schiller (1988) point out, the grinding plants are the greatest consumers of electric energy in the cement manufacturing process. They indicate that the average specific energy input required for cement grinding is about 40 kWh/tonne, i.e. almost 40 % of total electric energy requirement for cement manufacture. Most grinding plants are equipped with ball mills. These may be operated as open-circuit mills or in closed circuits with classifiers (air separators).

Energy losses in operating the mills are great, and should be limited as much as possible by an appropriate choice of the grinding process and of the operating conditions of the mill and the classifier. The principal factors affecting the energy input for cement grinding are:

- The set values of the ball mill;
- The design and mode of operation of the classifier;

- The grindability of the principal constituents of the cement

F <u>Cement Packing</u>

Cement is dragged from cement silos and packed into bags or as bulk-by-bulk loaders. No relation exists between operating time and stoppage of this stage with the other production stages.

6.2.2 Energy consumption in various stages of cement manufacturing

As mentioned previously, cement manufacturing depends mainly upon decreasing the size of material by crushing or by grinding to a high degree of fineness, so the process is high in electrical energy consumption.

Also, the clinker burning process is high in consumption of thermal energy; perfect burning is achieved at a temperature of about 1450°C.

Generally, the average specific electrical energy consumption in all production stages were calculated in Fuhais plant and distributed as shown in table (6.1).

According to a report submitted to the Commission of the European Communities COWI consualt, March and Main consulting team, 1993, the total energy consumption of a modern plant in European union is as follows:

- Fuel consumption = 3.24 + or - 0.1 MJ/kg clinker

  (775 + or - 25 kcal/kg)

- Power consumption = 0.36 MJ/kg cement

  (100 kWh/t cement)

The total energy consumption has the following breakdown:

- Raw meal preparation 30 %
- Clinker burning 30 %
- Grinding 40 %

Table (6.1)

Specific Electricity Consumption in Cement Industry

Production Stage	Specific Electrical Energy kWh / Tonne	Percentage (%)
Crushing	2	2%
Raw Meal Grinding	24	23%
Clinker Burning	22	21%
Cement Grinding	52	50%
Packing	2.5	2.5%
Miscellaneous	1.5	1.5%
Total	104	100%

Source: Jordan Cement Factories, Fuhais plant, planning department, energy section reports

The thermal energy consumption in the burning process of one tonne of clinker requires an average of 95 litres of fuel oil, which is equal to (700-900) kcal/kg clinker (equivalent to 2926-3762 kJ/KG), and this depends on the burning process.

6.3 Energy Management in Cement Manufacturing in Jordan

6.3.1 Preview

After going through the cement production process and demonstrating the high amount of energy (electrical and fuel) it is revealed from that the importance of energy management practices in the cement industries.

Bialy and colleagues (1993) have shown that the first step in achieving an energy management process is the "awareness of potential savings". If a proper assessment of potential overall energy cost saving is accomplished, the second and most important step can easily be realised. This second step is top management commitment. These assessments. along with pilot programmes or projects demonstrating the actual savings will guarantee top management commitment.

They emphasise that eliciting and maintaining support for energy efficiency programmes is facilitated if tangible results are obtained quickly. One benefit of this strategy is that quick results provide "success stories" that help to develop public and private support in the long term. Moreover, the authors point out the tremendous savings possible from just improving operating and maintenance procedures (these often equal the savings from capital-intensive retrofits). They also claim "there are strong political pressures in donor agencies, local governments, and the private sector to show concrete results within a year or two, before the people involved move on to other responsibilities" (Baily et al., 1993, p26).

In order to limit the energy consumption and to exert any possible actions to achieve consumption averages in line with universal standards a continuous and organised energy management system is needed. This is particularly true at the Jordan Cement

Factories where the consumption averages before the introduction of any energy management activity exceeded the standards by more than (10-15%). It is believed that control and precise measurement of energy consumption play an important role in the effective system of energy management.

Energy management can be defined here as a group of procedures, activities and programmes designed to change the energy consumption pattern and shape of the daily energy load curve in order to conserve energy, thus reducing the cost of cement produced.

Through the researcher continuous efforts to build an energy management system (which will be explained in detail in chapter eight) and utilising the ideas and the discussions of the energy committees continuous meetings, the researcher identified that the following provisions are needed and proved to be useful to achieve the aim and the goals of the energy management:

- Precise instruments, which are necessary to measure and monitor the quantities of electricity and fuel purchased and consumed. C. Barreriro stated that although electronic monitoring and processing important operating data is now a matter of course in process industry electrical energy is still monitored (by hand in most cement plant). The energy figures obtained cannot be clearly assigned to individual departments and groups of machinery. This inaccuracy makes it difficult to identify any existing potential for energy saving in other words energy consumption figures produced in this way are not suitable as a guide for rational use of energy.

Measurement equipment is a vital tool for energy data collection, which is the crucial point and precondition for achieving the goal to reduce specific energy consumption. According to EEBPP good practice guide no 231 prepared by UK Department of Environment (1998), the data needed for an efficient energy information system are based on three processes: data analysis, communication and action. The function of these elements is to turn the data into action and thereby improve energy performance.

- Existence of a central department for energy in the organisation's hierarchy to audit, record, report and control energy consumption. According to C. Barreriro the keystone is the development of the people. Also a fundamental precondition, which must be met in order to reduce the specific fuel consumption, is the development and implementation of energy management organisation system together with the plant operation. They have to form a close system for energy management cycle.

- Existence of an energy committee with the Energy Department Manager as chairman and other department managers as members.

- Existence of a flexible, dynamic and effective system for communication and co-operation between the various departments and the energy department.

The following paragraphs explain the philosophy of energy management at JCF.

6.3.2 Philosophy of Energy Management in Jordan Cement Factories

Jordan Cement Factories Company adopted a special philosophy, in the early 1990s, for managing and minimising energy consumption. This philosophy is the outcome of the research work of the author of this thesis in collaboration with the top and middle management of the company and also of their original ideas based on their experience as well as the experience of other cement industries. Physical concrete data and facts are prepared in the first place in order to recognise a need for action. Secondly, a true belief in the objectives is created in order to translate the recognised need for action into definite and defined activities. The elements of this philosophy are manpower, belief, energy information, perception and action. More detailed information about these elements is given below:

A) Manpower

Manpower is the link between manufacturing operations and organisations. All workers of different levels ought to participate and co-operate in order to achieve programmed targets. All participants in the energy management efforts should follow two fundamental steps among other steps, which are:

1- Collect evaluates and analyses information
2- Apply knowledge and experience.

B) Belief in the ability to achieve objectives and targets

The belief in the objectives and targets has a positive effect and is the basis of human giving. Therefore, we must foster this belief and create self-confidence among workers in order to achieve the desired objectives. (According to CIPEC annual report 1998-1999, energy management programs are designed to increase awareness of the economic benefits of improved energy use and the development of tools to remove barriers). This can be done by establishing short and long-term objectives, and by promoting and generalising the advantages that can be gained in the case of success in achieving these objectives. This can be done for all management levels from the top to the lower level management.

C) Information

An energy information system including the circulation and flow of information concerning energy issues guarantees that energy information reaches the specialists in order to enable them to take suitable actions at the appropriate time. (According to the EEBPP good practice guide no. 231 prepared by UK Department of Environment (1998), an energy information system consists of more than meters and PCs. It also includes all organizational procedures and methods that allow it to operate. The prime function of the energy information system is the support of energy management as part of the overall strategy of the organization.)

D) Perception

Staff working in energy management and utilisation, must have the ability to understand energy matters, through the following ways:

1. Developing new methods of energy consumption savings
2. Observing any deviation in energy consumption patterns
3. Receiving and disseminating information to and from each level of energy management at the appropriate time.

Clear objectives and guidance by the top management and the energy committee and continuous training programmes will ensure that they have the capability to achieve their targets. According to the EEBPP good practice guide no. 85 prepared by UK

Department of Environment (1998), a commitment to continuous learning or continuing professional development is a whole mark of professionals who have an obligation to maintain their professional competence.

6.3.3 Applying Energy Management Philosophy

The energy management and conservation philosophy can be translated from theory into practice. This can be done after the management enforcement of policies, by applying plans through which the energy management philosophy can be taken into account. From our practical experience in applying an energy management system in JCF, the plans should include the following:

- Establishing limited objectives and targets for long periods and identifying the time period for executing each one. In accordance to EEBPP good practice guide 186 prepared by UK Department of Environment (1996), it is important to secure senior management commitment. It will have been necessary to identify the potential for improvement and make commitments to achieving particular goals or standards of energy and environmental management. Objectives may be set out in the corporate policy statement and can be expressed as the desired outcome of a specific policy commitment. Targets have to be realistic, meaningful and achievable under normal operating circumstances.

- Establishing plans for executing the objectives in a way that includes the procedures and instructions of work and preparing the necessary forms. According to the same EEBPP reference above, once objectives and targets and in-house action plans have to be drawn up which drive the management process forward and guide managers in what has to be done to operate effectively.

- Studying energy consumption patterns and specify any deviation from the best practices targets in order to set plans for rectifications. According to EEBPP good practice guide no. 112 prepared by UK Department of Environment (1998). benchmarking is a very effective way to compare energy information and to help management to monitor the overall management consumption of an enterprise.

- Studying the types and specifications of the equipment used in the factory and sorting them out, according to energy consumption and potential for conservation.

- Detailed study of the production operation for all production stages.

- Set the plans according to the production stages, identifying thermal and electrical energy consumption of each stage.

- Identifying and analysing all excessive energy consumption points in each production stage in order to apply the necessary measures to deal with them. According to EEBPP guide no. 217 prepared by UK Department of Environment (1998), the energy usages analysis can be used to show how much energy is wasted during periods when your plant is idling. One can use meters for specific production zones or using portable meters and also can calculate quantities based on estimate of rates of usage and production/idling times, also you can obtain plant performance information from equipment suppliers. It is expected to find that the rate of usage of energy in non-productive periods is much higher than expected.
- Identifying the priorities and taking action to execute them.
- Following up and observing the actions applied.

- Preparing and analysing reports for the work executed.
- Evaluation of the work done, compared with established objectives and targets.

From the researcher practical experience in Jordan Cement Factories through the efforts to build an energy management system and with participation of energy management committees, it is found that by applying the above-mentioned points, it is possible to succeed in reaching the desired objectives and targets.

With this brief background about energy management philosophy, the principles of this philosophy can be used in real-life applications. The following section will discuss applications of the above-mentioned concepts pertinent to energy consumption in cement manufacturing.

6.3.4 Energy Management Policy In JCF

A) General

According to EEBPP good practice guide no. 186 and 200 prepared by UK Department of Environment (1996), formulating a policy for energy and environmental management can be a long and detailed process and can go to very heart of the organisation and its culture, a coherent energy policy statement provides the foundation to the planning steps. Successful polices can be recognised as having five key attributes (thrust, commitment, applicability, implementation and review) which convey senior management commitment and set performance standards that is the organisation to attain. Understanding performance indicators and how they can be used to shape the management effectiveness and setting performance is vital for formulating the energy policies.

Specific energy consumption (i.e. Kwh /tonne of cement, or kcal/kg clinker) is the main performance indicators input of energy management process in JCF. The output of such a process is the target value of such consumption, while the process activities are managed and controlled by energy management staff.

The target values of specific energy consumption in JCF are not far from the ones included in a report submitted to Commission of the European Communities in 1993 (COWI Consult, 1993).

Specific fuel consumption = 3.24 + 0.1 MJ/Kg clinker

Specific electrical power consumption = 100 Kwh / tonne of cement

The target value for specific electricity consumption is 100 kWh/tonne of cement for JCF that is identical to a European modern plant (COWI Consult, 1993). As a matter of fact JCF has already achieved 101 kWh/tonne of cement. For the specific thermal energy the target for JCF is somewhat lower than the European average plant consumption (830 Kcal/Kg) Vs 775 +-25 Kcal/Kg clinker because the JCF production lines are modern lines compared with some of the old established European ones. The JCF targets were based on the available manufacturing technology and the guaranteed performance figures and the practical experience in JCF factories. According to Rashadiya cement plant 1999 budget, energy cost is equal to 64% of variable cost and 31% of total cost. Thermal energy cost is equal to 47% of total energy cost and the rest is electrical power cost. The following table (6.2) shows the distribution of this cost on process stages.

Table (6.2)

Distribution of Energy Costs per Cement

Production Processes

Stage	**Elect. Power Cost.**	**Thermal Energy Cost**
Quarrying	-	5%
Crushing	2%	-
Raw Meal Grinding	23%	-
Clinker Burning	21%	94%
Clinker Grinding	50%	-
Packing	2.5%	-
Others	1.5%	1%

Source: Jordan Cement Factories Company-Financial department -Costing section

B) Methodology

Over a period of two to three years energy committees of relevant personnel met under the direct supervision and follow-up of the researcher to discuss and develop a framework for a practical energy management systems at both JCF plants. Initially these committees formulated ideas and plans about the content and style of the EMS, and a process of exchange and co-ordination between the two sites was established. The EMS, which finally emerged, was shaped by the experiences and feedback from operating the primary concepts and from modifying them as appropriate. From our practical experience to develop and implement an energy management system, the following methodology was developed and should to be followed to achieve the original guaranteed performance parameters, values and targets:

- Targets are defined as a result of mutual agreement between planning activities and production activities. These targets are defined yearly and used for budgeting purposes. According to EEBPP good practice guide no. 242 prepared by UK Department of Environment (1998), "setting targets or identifying how much energy a plant should be using- provides a benchmark against which a design can be compared".

- ☐ Monitoring of energy consumption is carried out by an independent group in the organisation (energy section). Deviation of actual consumption from planned is scrutinised whereby the plant manager and production manager take necessary action to correct this deviation.
- ☐ Suitable inspection and measurement equipment is used to assist the plant operators in recognising and correcting the deviations.
- ☐ Analysis and improvement.

  An energy committee at top management level holds a meeting every two months to review performance and to check for new improvement.
- ☐ Documented procedures and instructions are issued to ensure a flexible, dynamic and effective system for communication and co-ordination between production management and energy management.

C) Input

Input for energy management system is classified as follows:

- Targets for thermal and electrical energy specific consumption (i.e. kilo calories or Kwh per kg of clinker or tons of produced cement).

These targets of specific energy consumption are as follows:

- Diesel (L/tonne) for raw material quarried and transported
- Kwh/tonne for crushed raw material.
- KWh/tonne for ground raw material.
- KWh/tonne for clinker produced
- Kcal/kg for clinker produced
- KWh/tonne for finish grinding.
- KWh/tonne for packed cement.
- KWh /tonne for whole plant.

Targets for the parameters above (for control purposes) are decided for the next production annual plan for budgeting purposes. Planning staff, production staff and energy committee members together set up these values.

D) Control

Production staff monitors the real values of these parameters on daily basis. Planning and energy management staff performs this controlling function on monthly basis and corrective actions are taken.

E) Output

Results for the process from financial point of view are calculated on monthly basis.

F) New targets

New developments in technology of cement producing equipment, bench marking of JCF position to others, and energy committee recommendations are used to create new targets in energy consumption. For example, modifying burners, modifying fans impellers, using alternative fuels etc.

6.4 Factors and Methods of Energy Consumption Control

In the previous section we discussed the importance of the energy management policies and practices and the importance to set an energy management system for the systematic controlling of energy consumption. The factors and methods affecting the energy consumption will be discussed in this section.

As Rosemann and colleagues (1987) indicate, most cement clinker is now burned in dry-process rotary kilns with preheater equipment and clinker coolers. In the conventional burning process the fuel energy is supplied entirely to the kiln itself. On the other hand, with precalcining, the basic principle is that a substantial proportion of the fuel energy is introduced into the feed material outside the actual kiln, so that the calcium carbonate in the material is decarbonated (calcined) to a major extent before entry into the kiln. To achieve this "precalcination" a so-called secondary firing system (as distinct from the main or primary firing system in the kiln itself) is operated between the kiln and the preheater.

In the secondary firing system the calcium carbonate undergoes dissociation, i.e., is calcined, at temperatures around 820 °C. For this reason it is also possible to operate this firing system with low-grade "substitute" fuels or waste-derived fuels of relatively low calorific value which, on account of their properties, cannot (or can only to a limited extent) be used in the main firing system of the kiln. In new cement plants designed to operate with precalcining, the dimensions of the kiln can be reduced and the quantities of refractory materials required thus likewise reduced. Therefore, the advantage of the precalcining method lies in the relatively low capital expenditure and operating costs of the kiln plant.

The operation of a secondary firing system however, affects fuel energy consumption and also the operational behaviour of the kiln plant. Experience with actual plants has shown that with unfavourable operation of the secondary firing system, the fuel energy consumption plant may be appreciably increased. If too high a proportion of fuel is fired in the secondary system, coating formation in the lower part of the preheater and in the kiln inlet may occur, seriously upsetting kiln operation (Rosemann et al., 1987).

Another example of energy saving is provided by Igawa et al. (1987). In this case the modification targeted the cyclone preheater, whereby the principal change consisted in the development of a cyclone characterised by low-pressure drop and high collecting efficiency. An extra cyclone stage was added to the already existing four stages. The researchers reported that, as a result of this modification, the specific thermal energy consumption was decreased from 650 kcal/kg of clinker to 605 kcal/kg. Moreover, electricity consumption of the kiln exit gas fan dropped from 9.5 Kwh/t to 8.9 Kwh/t.

Vertesffy et al (1986) relate fuel energy consumption to kiln output as follows:
"As a rule, the specific fuel energy consumption for clinker burning is determined by the pyroprocessing technology employed. In addition, the operation of the kiln, the clinker output, the raw material consumption, and the preparation of the raw meal affect the specific fuel energy consumption" (p323). Also they indicated that "The specific fuel energy consumption of an existing cement kiln plant can therefore be calculated in terms of the clinker output; the feed meal composition; and the proportion of energy supplied as fuel to the secondary firing system" (p324).

Based on the researcher investigations and studies of the factories log books and log sheets in which all the production lines operation details are recorded, and based on the efforts to control the energy consumptions through analysing the cement manufacturing processes, the researcher found out that the main factors and methods that guarantee energy consumption control can be summarised as follows:

6.4.1 Stability of Operational Process

Continuity of operational process and avoiding breakdown stoppages considered one of the most important rules, which yield minimum energy consumption level. It also means increasing the availability to the maximum possible level. The statistical relationship between energy consumption and availability and other factors is clearly presented in Chapter 7. According to David Garcia (1992), the steady operational process and the optimisation of the operation system and optimisation of its operational variables through setting desired and predefined operational parameters is necessary to achieve the following condition:

- Minimization of energy consumption
- Maximization of production in terms of quantity and quality
- Absolutely regular stable operation.

Decreasing the number of stoppages can be achieved by taking the necessary actions among which are the following:

A) Maintenance

Preparing annual preventive maintenance programmes showing maintenance date, period, and all jobs that are intended to be executed by each technical department in the factory. Applying these programmes precisely, even with stability in the operational conditions, results in a decrease in the number and duration of stoppages or, in other words, an increase in equipment availability. This, in turn, results in a reduction of production losses and consequently, energy consumption. According to EEBPP good practice guide no. 217 (1998), there is a strong link between effective maintenance and energy efficiency. The more efficiently plant or equipment works, the less energy it uses.

B) Supervising & Controlling

Continuous supervision and monitoring of factory equipment with respect to meeting operational target guarantees steady production. According to EEBPP future practice profile no. 70 (1998), automatic plant monitoring is often used to diagnose impending plant failure and to schedule timely maintenance. Recent experience shows that it can also be used effectively to monitor energy efficiency of plant and processes and to diagnose the causes of poor performance.

C) Operational Efficiency

Operating the production lines with high operational efficiency requires skilled and highly experienced operators especially kiln operators. This helps in dealing correctly with any definite problem, and also helps in controlling the operational conditions. According to good practice case study no. 372 (1998), conventional control of cement kiln has its shortcomings, it require an experienced operator who will constantly interpret process conditions and make frequent adjustments to control set points. This task is made more difficult by complex responses, time delays and interactions between the individual process variables. As a result, conventional kiln control results in conservative kiln operation with temperatures that are higher than the optimum, and in unnecessary high-energy use. Advanced control system can improve on conventional control by constantly interpreting kiln conditions and initiating appropriate actions and can be of great support for the operator.

D) Quality Control

Quality control of all production stages is very important for stability and steady condition of operational process, especially for kilns, and prevents the stoppage of production lines for problems related to quality control. According to future practice profile no. 89 (1999), accurate control of temperature in industries using furnaces, ovens, kilns and incinerator is vital for quality control and safety and for monitoring unnecessary expenditure on fuels. The potential fuel savings available in UK cement and incinerators plants alone for colder temperature control are over 1.2 sterling pound per year.

E) Spare Parts

Availability of spare parts in the stores for use in programmed maintenance helps in performing maintenance work without unnecessary delays. It helps in stabilising the operational process as a result of decreasing the number and duration of stoppages.

6.4.2 Rate of Production

Keeping the productivity at a maximum level has a direct effect on energy consumption. The production line designed and optimised to consume the most efficient energy consumption at a pre sitted production rate, which is the full production rate, producing at low production rate will increase the specific fuel consumption and specific electricity consumption. According to M.K. Singhi et al (1987), suggested appropriate systematic phased modernising modifications using in-house expertise and capabilities reduces downtime and provides an opportunity to verify the outcome of each production stage in the cement plant before going to the next stage will improve productivity and energy conservation. The most important operational measures for improving overall productivity and reducing energy consumption include:

- Prevention of idle running of equipment by providing interlocking arrangement and operating them with a plc system
- Minimising ingress of false air into raw mill, kiln cooler and cement mill circuits
- Optimising raw mix design.
- Ensuring operational availability of various continuous running equipment by the preventive, predictive and condition monitoring system approach for maintaining good performance of the plant and the machinery.
- Efficient information management systems for identifying various important parameters for efficient operation of the equipment and taking timely remedial measures in case of abnormal behaviour of continuous running machinery.

The productivity of the production line usually affected by the following factors:

A) Operational Efficiency

The operator's role is considered to be essential in increasing productivity to the maximum possible level through controlling the operational process, which requires training and experience especially in kiln operation.

B) Stoppages

Keeping the number of stoppages to a minimum helps in stabilising the operational conditions and as a result, increases the productivity to a maximum level. Moreover, minimising the number of stoppages requires, as mentioned before, programmed preventive maintenance for all technical departments (Production, Electrical, Mechanical).

C) Air Infiltration

Minimising the volume of infiltrated air into the system to a minimum level results in an increase in the productivity and a decrease in the consumption of the electrical and thermal energy. This requires taking the necessary measurements and closing the holes and places through which air infiltrates. Infiltrated air increase the electrical load on the electrical motors without adding to the production, and also increase the heat losses through discharging the hot air from the process.

D) Feed Size

Minimising the size of feed particles, especially those entering the crushers, raw mills and cement mills, and in addition, keeping the fineness of raw meal entering the kiln within required limits, leads to an increase in the productivity and a decrease in energy consumption.

E) Humidity

The increase in humidity ratio of materials entering the production unit, especially the raw mill, leads to operational problems and therefore, decreases productivity and increases energy consumption.

F) Quality Control

Controlling and monitoring the quality in every stage of the production process results in uniform operational process, especially in kilns. This leads to lower energy consumption and increased production capacity.

G) Measuring Instruments

Calibration and precision of measuring instruments in the system are necessary to know the actual values of variables in the operational process and assist the operator in increasing the operational efficiency.

H) Maintenance of Quarry Vehicles

Providing enough vehicles for work assists in keeping the feed of crushers at maximum level, and the machines will not be working with no load.

6.4.3 Operational Efficiency

As mentioned before operational efficiency is essential in maintaining maximum production capacity and decreasing the number and duration of stoppages. In a case study presented in EEBPP good practice guide 217 (1998), for a company producing cement products, they found that the most significant energy losses were due to breakdowns, start-ups and minor stoppages. Operational efficiency also leads to steady operational processes, and this can be maintained by means of the following:

A) Training

Training is considered as an important factor in increasing the operational efficiency for the operators, especially for kiln operators who require training on the site or in factories having the same system. According to EEBPP good practice guide no. 200 (1996), raising awareness of energy issues by continuous training is an essential components of the management programs and should be tackled at all staff levels from the board room downwards, also transferring essential know-how to the people who will deliver the benefits of the energy management program.

B) Monitoring and Directing

It is essential to monitor the operational process and give the necessary directing orders to the operators; for instance it is necessary not to operate the machines while there is no production or during the stoppage of the main equipment of the production line, and to operate the equipment only during the appropriate time and manner.

6.4.4 Research and Development (R&D)

Performing the necessary studies and applying the appropriate tests and experiments for energy conservation are very important in solving the problems and obstacles, which prevent uniformity of process operation. Such R&D activities help in maximising production rate of the various production units, and help in preparing an annual energy plan to minimise energy consumption.

6.4.5 *Upgrading and Improvement*

Following up the latest developments in cement manufacturing technologies is very necessary for increasing the production capacity and decreasing energy consumption. As an example, a case study to improve the production capacity of cement mills in Rashadiya plant by 18% and to decrease the specific electric power consumption by 15% is presented later. This will help in decreasing the working hours so the need to operate the mills during daytime and peak hours will be minimised.

Furthermore, there is an intention to upgrade production line No. 5 in Fuhais Plant, so the production capacity will increase by 12% and the specific thermal energy consumption will decrease by 17%.

6.4.6 *Management*

Applying modern management techniques, implementing the total quality management concept and providing the requirements to obtain the ISO 9000 certification will lead to job fulfilment and improvement of performance, which will be reflected positively in the performance of production units. Consequently this will conserve the energy consumption and decrease the production cost.

Figure (6.1) shows the factors and means of controlling energy consumption distributed according to the fishbone method.

The fishbone method, which is also known as "cause and effect" diagram, is a schematic presentation of cause and effect relationship which represent the contribution of each of several factors on the specific rate of fuel and electricity consumption.

6.5 Thermal Energy Utilisation in the Cement Industry in Jordan

In the previous section we discussed the factors affecting the energy consumption, in this section we will analyse the thermal energy utilisation and the factors affecting it.

According to the cost analysis performed in chapter five, the thermal energy is calculated to be about 45% out of the total consumed energy in JCF. The yearly cost of thermal energy (fuel) is about 20 million JD (29 million dollars) depending on the produced amount of clinker and cost of fuel.

The following analyses are important for understanding the relationship between energy consumption and cement manufacturing.

6.5.1 Energy Utilisation in the Burning Process

According to FLS (a Danish company who are one of the biggest cement equipment manufacturers) in their study *The Energy Efficient Cement Plant*, obtained from the British Cement Association (undated), thermal quantity theoretically needed for combustion in kilns is about 408 kcal/kg clinker, whereas the active consumed thermal energy quantity is about 734 kcal/kg clinker for a 4000 tonne per day 5-stage precalciner kiln with a high efficiency grate cooler. Comparing with the essential need of thermal quantity used in burning (408 kcal/kg clinker), we find that the efficiency of thermal burning is still about (56%).

In practice, the total heat needed for kiln combustion is the quantity of heat theoretically needed for burning in addition to the heat lost by the system. System heat losses are:

- Sensible heat in the clinker leaving the system.
- Sensible heat in the exhaust gas, including dust, leaving the system.

- Heat of vaporisation of all water entering the system.
- Radiation and convection heat losses from the system.

According to the same study of FLS, total thermal losses are about 44% of the consumed thermal energy, distributed approximately as follows:

- Losses with exhaust gases 23%
- Losses from the cooling system 11%
- Losses by radiation and convection 10%

These are the main factors that can be worked through in order to reduce thermal expenditure. Some of the thermal losses cannot be totally avoided, but they can be minimised.

Reducing the heat losses has a mutual effect on both thermal and electrical energy consumption. For example, due to recovering actions of sensible heat in the clinker leaving the system by increasing secondary air temperature entering the kiln, the flame temperature will rise, resulting in improved efficiency of heat transfer. This means that a large amount of heat will be transferred to the material while some heat will stay in the gases. The difference between the temperature of materials and gases is about (500-600 °C). This leads to a reduction in volume of gases with small heat loss, resulting in a reduction of fuel consumption and electrical energy consumption for the kiln fan (IDF) and also for the cooling waste fan.

6.5.2 Analysis of the factors affecting the specific rate of thermal energy consumption

The specific rate of thermal energy consumption is measured by calculating value of kilocalories consumed per one kg of clinker. Instantaneous control of this paramcter is carried out by controlling gas temperatures, gas flows, CO and O2 percentages, density of clinker produced and burning zone temperature.

This rate is connected directly with the quantity and quality of produced clinker. For the sake of reducing production cost, every effort must be exerted to make the specific rate as low as possible.

The present fuel energy consumption situation in Rashadiya plant is as follows:

- Specific rate of thermal energy actual consumption is 840 kcal/kg
- Designed specific rate of thermal energy is 760 kcal/kg
- Increase of specific rate of thermal energy is 80 kcal/kg.

It has been proven through preliminary factory studies and experimentation and actual observation in Rashadiya plant performed by task forces consisting of engineers from different departments with major role of the following engineers Adaileh, Alamer and Zaza to correct the deviation. It revealed from these studies that there are many reasons for the rise of the specific rate of fuel consumption. The specific thermal energy consumption indicates the degree of the burning efficiency, this is also related directly to the quantity and quality of produce clinker, for the sake for reducing the production cost all efforts directed towards reducing the specific thermal consumption.

The actual specific thermal energy consumption was 840 Kcal/Kg clinker. Designed specific thermal energy consumption is 760 Kcal/Kg clinker. Increase in specific thermal energy consumption is 80 Kcal/Kg clinker. According to the data collected and observed, the most important reasons, summarised and distributed in percentage according to the Fishbone method as shown in figure (6.2) are as follows:

6.5.2.1 Decrease of Production Rate (70%)

Decrease of production rate and the inability to reach the designed production rate is due to the following:

- Maintenance and equipment efficiency 22%

- Operators' lack of skills and dedication 18%
- Quality control and material mixing 12%
- Measuring equipment accuracy and calibration 10%
- Air leakage into the system 5%
- Low level of material in silos 3%

6.5.2.2 Availability and Stoppages (duration and number) (30%)

The poor availability and increased number and duration of stoppages of the operational process which cause instability and untidiness of operational process have direct effect on increasing the specific rate of thermal energy consumption for the following reasons:

- Maintenance: Maintenance programmes are not applied; maintenance supervisors and workers are not skilled enough 9%
- Lack of spare parts 6%
- Technical problems are not deeply studied 5%
- Operators lack concern and experience 4%
- Inadequate supervision and observation 3%
- Quality control and avoiding rings and coatings inside kiln are not taken into consideration 2%
- Preheating due to stoppages 1%

6.6 Electrical Energy Utilisation in Cement Industry in Jordan

In the previous section we analysed the factors affecting the thermal energy consumption, and the other part of the energy consumption, which is the electrical energy, will be discussed in this section.

From the energy cost analysis, which performed in chapter five, it revealed that the electrical energy cost is around 55% out of total energy consumed needed for cement manufacturing.

Fuhais and Rashadiya factories are supplied with electrical energy by Jordan Electricity Authority, which provides about 75% of the needed electricity for Fuhais Factory and 100% of needed electricity for Rashadiya Factory, with the following defined tariffs (issued by Jordan Electricity Authority):

1. Daily supply cost: 47 fills/kWh, during the daily 16 hours (from 7 in the morning until 23 hours.).
2. Nightly supply cost: 25 fills/kWh, during 8 hours of night-time, (from 23 hours. until 7 in the morning).
3. Maximum load cost: 2400 fills/kW of monthly maximum load during peak time (from 17 hours until 20 hours wintertime and from 19 hours. to 20 hours. summer time).
4. Power factor: when the power factor is less than (0.85) an extra charge is paid in addition to the electricity bill.

   Fuhais Factory is also fed from a standby diesel power station. installed by the factory. Its production capacity is about 50,000 MWh a year, with a cost of 35.4 fills/kWh.

6.6.1 Electrical Load Management

In addition to the energy consumption control factors mentioned previously, utilisation of electricity tariff structure in planning and implementing the scheduled operation of the production units is very important and essential in energy consumption utilisation and control. Therefore, efforts must be concentrated on night-time use of electrical energy by operating those production units, which have high availability and can be stopped and operated easily, such as crushers and mills and stopping the other unnecessary equipment during the peak load period.

A study was made with the participation of the diesel power plant staff with main participation by engineer Salem Amer to show the saving achieved by applying a proper electrical load management, in addition to running the standby electrical power generator, in the peak load period:

1983 was taken as the base year in comparing cost for peak load for each kWh consumed until 1991. The year 1983 was taken as a standard for comparison for the following reasons:

- Production line No. 6 was installed in 1982, and worked steadily in 1983.
- All production lines were working at full production capacity.
- Electrical loads operating management policy was applied.

The following calculations were then made:

- The sum of all electrical energy cost bought from Jordan Electricity Authority and the standby power station since 1983 until 1991.
- The sum of peak load cost for the years from 1983 until 1991.
- The sum of additional cost for the each kWh consumed due to peak load charge for the years from 1983-1991.

$$= \frac{\text{sum of peak load fine cost}}{\text{sum of consumed electrical energy}}$$

- The difference of additional cost for each kWh consumed due to peak load charge from 1983 to 1991.

= added cost / kWh due to 1983 peak load - added cost /kWh for the year to be compared.

- Achieved savings for each year due to the decrease in peak load cost, which equals difference of added cost/kWh due to peak load multiplied by sum of consumed electrical energy.

For example calculating saving for 1984 is as follows:

Sum of peak load in 1983 = 250 MW

Sum of peak load in 1984 = 175 MW

Cost of peak load fine = 2400JD/MW

Sum of Kwh consumed in 1983 = 50975830 kWh

Sum of Kwh consumed in 1984 = 44370080 kWh

$$\text{Saving factor} = \frac{250\text{MW} \times 2400\text{JD/MW}}{50975830\ \text{kWh}} - \frac{175\ \text{MW} \times 2400\ \text{JD/Mw}}{44370080\ \text{kWh}}$$

$$= 0.0023\ \text{JD/kWh}$$

$$\text{So saving for 1984} = 0.0023\ \text{JD/Kwh} \times 44370080\ \text{Kwh}$$

$$= 102{,}051\ \text{JD}$$

- Total savings achieved through applying electrical load management policy, which was 589685 JD

- Table (6.3) shows in detail the generated power in kWh for each year, which are used to calculate achieved savings for each year. IT is clear that there was concentration in utilising the diesel power plant in early eighties so as to save in the cost of energy. In mid eighties, there was slacken effort, which result in decreasing the dependence on the diesel power plant, and an awareness of the advantages of running the diesel power plant was demonstrated again at beginning of nineties.

Table (6.3)
Electrical Energy Produced by Power Station
(Diesel Power Station)

Year	Generated Power (kWh)
1980	55585810
1981	46542110
1982	52584660
1983	50975830
1984	44370080
1985	34902980
1986	16870750
1987	18139040
1988	15284100
1989	7739900
1990	16058100
1991	41505800
1992	40444700
1993	36117900

Source: Jordan Cement Factories, Fuhais Factory Annual Reports

6.6.2 Operating Diesel Power Station in Fuhais Plant in Parallel with the National Network

The diesel power station was feeding line No. 4 only, and there was no possibility of connecting it in parallel with the national network for technical reasons. Due to the high cost of electrical energy bought from the national network, a feasibility study was done by the diesel power plant staff headed by engineer Salem Amer and under the direct supervision of the researcher, and action was taken to renew the diesel power station in order to connect it in parallel with the national network during the day time with maximum load and also to reduce the peak load to the least possible.

6.6.3 Calculation of savings achieved due to renewing diesel power station

The diesel power station was renewed and connected in parallel with the national network (Jordan Electricity Authority) in June 1987. From that time, it started to reduce the cost of electrical energy.

Principles of calculations:

- As production capacity of diesel power station is 10.5 MWh, so the value of 10 MWh is considered as the average of peak load compensated by diesel power station to reduce the peak load supplied by the national network.
- Cost of kWh, bought from Jordan Electricity Authority before 1/10/1990 during the daytime was 17 fills.
- KWh average cost produced from the diesel power station was 25 fills.
- Tariff of each kW during peak hours was 2400 fills/kW/month

The diesel power station was running with full capacity during peak time, which was 3 hours daily. The equation applied for calculating savings and losses due to running the diesel power station is as follows:

Saving amount (JD) = PG x Tpeak x M + EG* (Tnet - TG).

Where: PG = Peak load generated by power station (=10MW).

Tpeak = Peak load tariff (2.4 JD/kW).

M = Number of months

EG = Electrical energy generated by power station (kWh)

Tnet = Electrical energy cost bought from national network (JD/kWh)

TG = Electrical energy cost generated by power station (JD/kWh)

Total savings in 1987:

As the diesel power station started running in June, the calculation of savings started after that month:

PG	=	Peak load generated by power station =10MW.
Tpeak	=	Peak load tariff = 2.4 JD/kW.
M	=	Number of months = 7
EG	=	Electrical energy generated by power station =9622100 kWh
Tnet	=	Electrical energy cost bought from national network
	=	0.017 (JD/kWh)
TG	=	Electrical energy cost generated by power station
	=	0.025 (JD/kWh)

Total saving in 1987 = 10000 x 2.4 x 7 + 9622100 (0.017 - 0.025)

= 91.023 JD

Total savings in 1988:

10000 x 2.4 x 12 + 15284100 (0.017 - 0.025) = 165,727 JD

Total savings in 1989:

10000 x 2.4 x 12 + 7739900 (0.017 - 0.025) = 226,080 JD

Total Savings in 1990:

The kWh Tariff bought from Jordan Electricity Authority (JEA) during the daytime was raised to 39 fills, and the nightly Tariff to 22 fills, from the beginning of 1/10/1990. From that date, the cost of electrical power from JEA during the daytime was much higher than the cost of kWh, produced from the diesel power station. Consequently, a new policy was applied to have the diesel power station running throughout the day, i.e., from (7-23) hours, with maximum productivity.

Savings before 1/10/1990

10000 x 2.4 x 9 + 5657100 (0.017 - 0.025) = 170,743 JD

Savings after 1/10/1990

10000 x 2.4 x 3 + 10401000 (0.039 - 0.033) = 144,807 JD

Total savings during 1990

170743 + 144807 = 315,550 JD

Total savings during 1991

10000 x 2.4 x 12 + 41505800 (0.039 - 0.033) = 578,541 JD

Total savings during 1992

10000 x 2.4 x 12 + 40444700 (0.039 - 0.033) = 578,541 JD

Total savings during 1993

10000 x 2.4 x 12 + 36117900 (0.044 - 0.037) = 540,825 JD Therefore, total saving value achieved over 8 years due to operating the power station in parallel with the national network = 2,812,137 JD

6.6.4 Analysis of the factors affecting the specific Rate of Electrical Energy Consumption (kWh/Tonne):

According to FLS (reference as section 6.5.1), the modern dry processes designed plant have the following optimum designed electricity consumption per tonne of cement shown in table (6.4).

Table (6.4)
Energy Consumption Dry Process Cement Plant

Stage	Fuel Kcal/Kg cement	Electricity Kwh/tonne cement
Quarry	-	0
Crushers	-	2.5
Prehomogenizing and transport	-	1.5
Raw mill	0-100	27
Raw meal silo	-	1.5
Kiln feeder	-	1.5
Kiln and cooler	720	23
Coal mill	-	2.5
Cement mill	-	30
Packing plant	-	1
Other	-	4.5
Total	720-820	95

Source: FLS paper (The energy efficient cement plant, reference as section 6.5.1)

It is worth mentioning that the specific electricity consumption per tonne of cement can be varied between one plant to another depending on the raw materials used, type of the fuel used, and types of additive material etc.

According to Eng. Abo Dabaat the head of energy section in JCF the specific rate of electrical energy consumption, which is the reference for monitoring and controlling the electrical energy, consumption varies between (102-120) kWh/Tonne, depending on the system used for each production line.

Taking line No. 6 in Fuhais Factory and the two production lines in Rashadiya Factory (as these lines are alike), we can see that specific rate varies between (102 - 114) kWh/Ton.

Electrical energy consumption in Jordan Cement Factories, according to energy consumption records of the energy section, is distributed approximately as follows:

- Cement mills 50%
- Raw material mills 23%
- Kilns 21%
- Crushers 2%

- Packing plant 2.5%
- Others 1.5%

Calculation of electrical energy consumption must concentrate first on cement mills then on raw material mills and kilns, taking into consideration the consumption in other units.

The increase in specific rate for electrical energy consumption revealed from the same factory studies performed by factory task forces consisting of engineers from different departments with major role of the following engineers Adaileh, Alamer and Zaza. Specific electrical energy consumption is directly proportional to the production rate, availability and stoppages, where actual specific electricity consumption according to Rashadiya energy section reaches to 112% of the optimum value. According to the Fishbone method shown in figure (6.3), the factors affecting the electrical specific consumption can be divided into the following:

A) Stoppages and Availability

Specific rate is affected by the availability and number and duration of stoppages, especially in kilns and raw material mills areas, where the main equipment may continue running with no load for a long time, leading to waste in electrical energy consumption. Furthermore, start-up of equipment after shutdown will need additional electrical power. It should be mentioned that increased stoppages decrease availability.

The above mentioned preliminary internal studies carried out by the technical staff of the factories have shown that stoppages are responsible for about 50% out of the total ratio of the increase in electrical energy consumption, is distributed as follows:

1. Not applying maintenance programmes 30%
2. Inadequacy of technicians' skill and dedication 8%
3. Lack of operational efficiency to reduce stoppages 5%
4. Poor quality control 2%

5. Lack of spare parts 2%

6. Inadequate monitoring and inspection 2%

B) Decrease in Production Rate

As a cement mill consumes 50% of electrical energy, so any decrease in production rate will directly affect the increase in electrical energy consumption in addition to the same effect of the production rate of decrease in raw material mills and kilns.

These studies have also proven that the decrease in production rate is responsible for 50% of the total ratio of increase in electrical energy consumption, which is distributed as follows:

1. Decrease of equipment and maintenance efficiency 15%
2. Decrease in operational efficiency 12%
3. Air leakage 5%
4. Clinker temperature and quality 4%
5. Measuring devices 3%
6. High smoothness 3%
7. Feed size 2%
8. Quality control 2%
9. Storing materials 2%
10. Humidity 1%
11. Quarry vehicles availability 0.5%
12. Tearing of cement bags 0.5%

It can be concluded that electrical energy consumption can be decreased by being strict about the time schedule and efficiency of programmed maintenance; increasing the efficiency of equipment; and streamlining the operational process. Moreover, technicians at all levels must be highly skilled and concerned about efficiency.

The previous percentages mentioned in 6.5.2 and 6.6.4 are based on preliminary studies and need to be supported with other studies, because to reach an accurate percentage we need to build up a sophisticated statistical model, which we are going to pursue in chapter seven. But no doubt that the above empirical analysis based on practical experience, continuous follow up of causes of stoppages and shutdown, decrease in availability, variation in loading rate, continuous monitoring of fuel and electrical energy and the causes of that variation represent a strong ground to develop the research steps towards building up a viable and useful statistical model to predict the energy consumption variations and the factors affecting it.

6.7 Energy Conservation in the Grinding Process

In section 6.6 we studied the factors, which affect the electrical energy consumption and the possibilities of saving, and as a part of this exercise it is important to identify the equipment with the major percentage of consumption (bulk consumption). The main electrical energy consumer in the cement plant is the Cylindrical grinding equipment that consumes a very large quantity of electrical energy. When such equipment is loaded, the increase in electrical energy consumption is relatively low, in comparison with total electrical energy consumed, so they are called "constant power machines". According to Saxena J.P. et al (1995), approximately 60-70% of the total electrical energy used in a cement plant is utilised for the grinding of raw materials, coal and clinker.

As stated by H. G. Ellebrock et al (1988), the grinding plant is the greatest consumer of electrical energy in the cement manufacturing process. The greater part of the energy used for operating the mills is lost and it is important to limit the energy losses as much as possible by appropriate choice of grinding process and of the operating conditions of the mill and the classifier. The principal factors affecting the energy input for cement grinding including: the set value of the ball mill, the design and mode of operation of the classifier and the grind-ability of the principal constituents of the cement.

It is very important when running grinding equipment that conditions are optimised to get the highest production rate possible, in order to reduce the electrical consumption for each produced Tonne (kWh/Tonne), through the following measures, which resulted from the factory and the industry experience:

- Periodic inspection of mill liners and diaphragm slots in order to make sure the mill is free of blockages for air to flow through.
- Proper ball charge with proper ball size and graduation of size in each compartment.
- Correct feed size for clinker and gypsum entering the mill particles fed into the mill must be very small. This is ensured by maintaining hammers and grizzly bars for both clinker and gypsum crushers).
- A good maintenance programme and a proper programme for ball additions.
- Provision of suitable tables for registering information, in order to maintain those conditions.

According to Holderbank cement seminar (1997), support the measures mentioned above and add to it the importance of minimum interruptions in operation by external factors (lack of feed material, electricity failure, other shutdowns, ... etc.

The following information is usually registered in those tables:

- Ball charge level;
- Ball additions;
- Clinker feed size;
- Production quantity (Tonne per hour);
- Smoothness of product (Cement Blaine number);

- Mill energy consumption (kWh per hour);

In closed circuit mills, the separator has a direct effect on energy consumption. For that reason it should be kept under periodic maintenance to keep it active. According to Saxena J. P. (1995), an obvious means of improving performance of a ball mill is to equip it with an efficient separator. High efficiency separation improves the grain size distribution, increases production and reduces the grinding power requirement to 8-15%.

Grinding aids are very useful for increasing the mill's productivity. Formation of soft materials on balls is an example of such aids. Use of special liners, like classifying liners, and high chromium cast balls, as grinding aids also increases mill productivity. These have the added advantage of being highly resistant against corrosion, which keeps the balls going for longer periods. According to Nihon Cement Co. Textbook (undated), grinding aids prevent ball coating and consequently mill efficiency is increased and improving the energy consumption.

Hardness of clinker has a great effect on energy consumption in mills. The main standard factor for controlling clinker grinding is the hardness of cement product. Poor quality clinker needs an increase in energy consumption of about 40%, in order to render it sufficiently fine, hard, with good porosity, and with a proper crystal structure.

Factors affecting these specifications are:

- Metallic and chemical composition of raw meal
- Distribution and homogeneity of clinker feed size
- Cooling rate. According to Duda (1977), the clinker, which was slowly cooled in a rotary cooler, shows higher specific power requirements for grinding.

The only device that can be used to check the clinker quality is called microscopic examination equipment, which is not expensive and is easy to use.

Figure (6.4) shows the relation between energy consumption of the grinding process and fineness of cement product.

Grinding hot clinker results in decreasing mill productivity, which results in an increase in energy consumption for each ton produced, and also shutdown of the mill, when it is over-filled.

Grinding raw materials has noticeable results in reducing energy consumption. If raw material is made fine enough, the burning process in the kilns becomes more effective. According to Labahn et al (1983), the rates at which reaction takes place are generally dependent on the particle size of the reactants, i.e. on the reactive surface area. Hence the raw meal should be of such fineness that in the burning process even if it's coarsest particles will react as completely as possible. As a role, this condition is satisfied by cement raw material with a residue of not more than 5-20% by weight returned on 90 micron sieve. In Jordan Cement Factories, raw materials are grinded to a fine degree, which varies from (80-85%) passing through a sieve of 75 micron (200 mesh). The difference in grinding between 80% of material passing once through a sieve of 75 micron, and 70% passing through the same sieve, means about 20% saving in power used for grinding. Figure (6.5) shows the relation between energy consumption of the grinding process and fineness of raw materials.

For vertical roller mills, the decrease in gas flow into mill will reduce the fall in pressure through the mill and the electrical energy consumption of the mill fan. According to Duda (1977), the design of one of the vertical mills shows in the area of the grinding tools a relatively large free cross section, this result in an adequate lower pressure drop in the mill. Reducing pressure drop as much as possible will result in an increase in mill productive capacity, and a decrease in mill fan load, so a decrease in electrical consumption of the fan can be achieved. According to Saxena J. P. (1995)

vertical roller mills consume 15-30% lower specific energy than conventional ball mills.

6.8 Effect of Quality Control on Energy Consumption

As demonstrated in the previous sections steady state operation of the production line is of great importance to control the energy consumption. Quality control of the products through all the cement manufacturing stages (starting from quarrying and ending with the packing plant) is a very important factor, for having steady operational conditions in all production stages, and hence it affects specific consumption of electrical and thermal energy. More details and analysis on this issue is given below:

6.8.1 Effect of Raw Material Quality Control on Energy Consumption

According to Eng. Kanaan Amayreh, the quality manager at JCF, the quality of the main raw material needs to be controlled by taking periodic samples from the crusher in order to:

- Minimise the addition of insoluble additives like sand (quartz) and Pozzolana and hence prepare materials easy to burn in the kilns, which reduces thermal energy consumption.
- Supply materials, which have the same metallic and chemical composition, to have a stable thermal load in the kilns.
- Supply materials according to the required specification to get good products for the kilns.

6.8.2 Effect of Fine Grinding on Energy Consumption

There are two stages for grinding in cement manufacturing. The first stage is grinding raw material to render it very fine so that it feeds and burns easily. According to Blue

Circle Cement Technology Course (1977) the finer the raw materials the lower the combinability of the clinker and the smaller the allite crystal size, which will facilitate the raw materials burning. The fineness of the raw materials increases the reaction in the kiln, which depends on the surface area of the particles. The second and final stage is finely grinding the kiln products with added material such as Pozzolana and gypsum. in order to increase the liquidity of cement and reach the required hardness as we explained in section 6.7. For a cement mill, the fineness of material required (in order to get the required efficiency) changes from time to time. Fineness for Pozzolana Portland cement produced in Fuhais cement factory varies from 3-5% through a sieve of 63 microns.

According to Eng. Kanaan Amayreh, the quality manager at JCF, the main factors, which cause cement fineness standards to vary from time to time, are:

- Percentage of added Pozzolana: 20% in summer time and 10% in winter time, because of the high humidity of Pozzolana in winter.
- The quality of added clinker from the outside field varies due to mixing it with clinker from the silo. Therefore, limiting the amount of clinker stored outside has a great effect on grinding capacity.

6.8.3 Effect of Homogenous Raw Meal on Kilns Energy Consumption

Supplying kilns with homogenous feeding has a great effect on burning stability and thermal load stability in kilns. Producing a good quality of clinker does not need high-grade fineness in order to get the required hardness. Therefore, controlling homogeneity of materials is very important, starting from the raw meals in the primary storage fields, until the mixing silos, which play the main role in creating homogenous materials. As homogeneity is a very important factor for energy consumption, there should be plans laid out for increasing mixing efficiency inside silos. Blue Circle

Cement Technology Course (1977), showed how composition and fineness of the raw material mix, and the burning and cooling processes to which it is subjected affect cement quality. The cement quality depends not only on chemical composition but also influenced by the physical nature and crystal structure of clinker. According to Lafarge 10 basic facts on clinker (2000), decreasing raw mix rejects helps reduce burning temperature and help in reducing cement grinding energy. Also according to Lafarge 10 basic facts on burning (2000), uniformity in burning reactive raw mix improved burnabilty and easier to grind clinker.

As consistency of raw meal is a basic operational requirement, attention should be paid to the following:

6.8.3.1- Lime Saturation Factor

Lime saturation factor is defined by Duda (1977) as the ratio of the effective lime content to the maximum possible lime content in the clinker. In cement manufacturing calcium carbonate is the chemical, which requires the highest amount of heat to be produced, as in the following equation:

$$CaCO_3 = CaO + CO_2 - 698 \text{ Kcal / kg.}$$

As calcium carbonate forms (70-75%) of raw meals for cement manufacturing, working with a calciner which has a relatively low saturation factor leads to a decrease in fuel quantity needed for carbonate, and a drop in combinability temperature.

Figure (6.6) shows the relation between lime saturation factor and temperature needed for combination. It has been experimentally proven by the production and quality control departments with the collaboration of energy section that reducing (L.S.F) by about 5% will result in a decrease of heat between (10-20 kcal/kg), this is consistence with the figure content.

6.8.3.2- Silica Ratio

Silica ratio is defined by Duda (1977) as the proportion of SiO2 over iron oxide plus Alumina oxide. Controlling the silica ratio to keep it within the required range guarantees that the kiln will not be fed with a hard burning raw meal, which increases thermal energy consumption, producing uncontrolled operation, and a product which contains free lime.

6.8.3.3- Alumina Ratio

Alumina ratio is defined by Duda (1977) as the proportion of Alumina to iron oxide. Although iron oxide has a great effect in creating the liquid phase which helps in forming mineral clinker, especially when free silica is found in raw meal, experiments of the production and quality control departments have proven that an Alumina ratio of (1.38) gives better burning conditions inside kilns, due to the creation of a greater liquid phase with the least possible temperature.

The effect of the above three factors, among other variables, on energy consumption will be statistically investigated in Chapter 7 in order to demonstrate the effect of quality control on energy consumption.

6.8.3.4- Circulation Phenomenon

As stated by Duda (1977), substances like alkalis, sulphates and chlorides must always have constant ratios in raw meals. These materials have a strong effect, such as the circulation phenomenon in kilns; they evaporate at very high temperature (burning area), consuming a large quantity of heat, then recombine with colder areas (feeding end and precalciner), transferring the high temperature to these areas. This causes blockages and sometimes stoppage of kilns. To avoid this phenomenon, a bypass is used in kilns with a preheater and a precalciner, with an increase in fuel expenditure.

6.8.4 Effect of Clinker Quality on Energy Consumption

Clinker quality is directly related to the degree of cement fineness. Therefore, clinker quality is also related to energy consumption. The clinker quality is controlled each hour by measuring the density of the clinker gram/L (liter weight), and free lime. According to Lafarge 10 basic facts on clinker (2000), increasing sulphate content in the clinker (SO3) beyond the molar saturation of alkalies results in an increase in clinker fineness, which will leads to an increase in grinding energy (1% excess SO3 will cause an increase of 5 Kwh/tonne of cement). *In the case of quality deviation, action is* taken in the quality control department or the production department.

6.8.5 Effect of Cement Additives Production on Energy Consumption

As clinker production consumes a large quantity of electrical and thermal energy, adding additives with cement properties with a ratio of 30% will lead to energy saving. Such materials include natural Pozzolana, ashes produced by thermal power stations, and limestone. Adding these materials decreases energy consumption, but the efficiency of this practice depends on the following:

- Dryness of materials;
- Storage of materials;
- Supplying materials;
- Hardness;
- Effect on cement quality.

Because it is easy to grind some of these materials, compared with the clinker, grinding energy is reduced. Jordan Cement Factories studied the effect of adding some kinds of natural Pozzolana as an additional material to Portland cement. with 20% as a maximum ratio. This resulted in a reduction in the cost of produced cement by more than 400,000 JD (600,000 U.S dollar) per year.

It should be mentioned here that adding Pozzolana improves cement quality; it becomes harder and more resistant to expansion and to sulphate compounds. Jordan Cement Factories have made studies specifying the effect of adding some materials to Portland cement and Pozzolana Portland. For example. one study conducted jointly by production and quality control department concerning the effect of adding limestone, found that: limestone increases the hardness of Portland cement to maximum value and early hardness of Pozzolana Portland Cement. As most countries in the world use (3-5%) of limestone with cement material, Jordan specifications recommended an addition of 5% limestone for cement manufacturing.

6.9 Case studies

The following case studies are presented to highlight the importance, potential and applicability of energy management measures in JCF, which was discussed in the previous sections. It was carried out under the supervision of the researcher and performed by task forces from the production department, energy section staff with the participation of some other technical sections in accordance to the requirements. These case studies were submitted in " Energy conservation in JCF" paper by Halawani et al (1994) to the 8th international technical conference on cement and building materials held by the Arab Union for Cement and Building materials in Cairo/Egypt 15-20 Dec 1994. The technical data included in these case studies were obtained from Technical specifications book for equipment 1981, Rashadiya plant, Kobe Steel Ltd. The operational data were obtained from the operator log book and the operator log sheet.

The case studies presented below prove that there is a certain effect on energy consumption (electrical and thermal) from most, if not all, of the factors mentioned in the above analysis. However, the degree of relationship among any of these factors and energy consumption can only be determined through a statistical analysis model. although empirical evidence is available. The main benefit of the case studies are to demonstrate an actual true success story supported by figures and actual implementation which will convince all the concerned parties about the importance and the effectiveness of the energy management practices.

6.9.1 Energy Conservation in Cement Kilns in Rashadiya Plant

This study was made for the sake of decreasing electrical and thermal energy consumption for cement kilns in Rashadiya Factory/Jordan Cement Factories for a period of six months, (from 1/6/1993 until 30/11/1993).

Rashadiya technical specifications were as follows:

Technical Specifications:

- Process	S.P. Precalciner kiln.
- Kiln dimensions	4500 mm X 70000mm
- Preheater type	Suspension preheater with D.D.F. Precalciner
- Cooler type	Reciprocating gate
- Kiln output	3200 Tonne/day
- Design specific Heat consumption	760 kcal / kg
- Present specific Heat consumption	840 kcal / kg
- Fuel L.H.V.	9700 kcal / kg
- Fuel properties	Bunker C heavy oil

- Specific power consumption 20 KWH/Tonne

Operational Data:

Average operational data during study were as follows:

- Clinker production	3000 Tonne / day
- Kiln feed rate	205 Tonne / H
- D.D.F. oil flow	7.79 M^3 / H
- Kiln oil flow	4.1 M^3 / H
- Specific heat consumption	840 kcal / kg
- D.D.F. outlet temperature	890 °C
- S.P. outlet temperature	385 °C
- I.D. Fan inlet temperature	270 °C
- Tertiary air temperature	790 °C
- Burning zone temperature	1450°C
- Cooler waste gas temperature	250 °C
- Kiln feed end pressure	2 mbar
- D.D.F. outlet pressure	8 mbar
- 4th stage outlet pressure	12 mbar
- S.P. outlet pressure	46 mbar
- Kiln speed	2.1 mbar
- I.D.F. speed	620 rpm
- Kiln I.D.F. power	maximum 1600 kWh
- L.S.F.	97
- Silica ratio	2.5
- Alumina ratio	1.75

Gas samples were taken from different places in the kiln, and were analysed by means of a gas analyser device. The results were as follows:

	O_2%	CO%	CO_2%	N_2%
Kiln feed end	3.5	0.012	10	86.48
4th stage	4	0.018	30.5	65.49
S.P. outlet	5.8	0	27	67.2
I.D.F. inlet	7	0	23.8	69.2

Total gas volume at exhaust fan is I.D.F. 3660 Nm^3/min where gas volume at normal conditions without infiltrated or excess air according to kiln heat balance is = 3000 Nm^3/min.

It was concluded, after analysing gas samples and noticing the operation data and conditions, that air infiltration took place in the following places:

1. Kiln hood: side holes, main gate and burner inlet.
2. Kiln outlet seal ring.
3. Kiln feed end.
4. Heat exchanger, expansion joints, gates and inspection holes.
5. Gas stabiliser, discharge gates and screw conveyor.
6. I.D. Fan gates.

When the production line under study was shut down for general maintenance, the following actions were taken in order to avoid air infiltration into the system:

1. A kiln outlet seal ring was installed.
2. A new seal ring was installed between the kiln and transition housing.
3. Kiln hood: the holes of the kiln gate were closed with movable metal sheets that can be opened for inspection purposes and then closed automatically. The iron seal ring

around the burner inlet to the kiln was fixed to avoid air infiltration and bricks were laid to close the gates of the kiln hood.

4. Preheater: the gates were closed using bricks and holes in the expansion joints' tubes were soldered.
5. Cooling power: A new double flap was installed and general maintenance carried out.
6. Exhaust fan: Holes on the expansion joints tubes were soldered and the gates made to close perfectly.

After applying the above steps, the line was run and the same result was obtained; productive capacity was 3000 ton / day. The previous study was carried out again using other samples, measuring and analysing them, using the gas analyser device. The results were as follows:

	O_2%	CO%	CO_2%	N_2%
Kiln feed end	2.5	0.02	12	85.98
4th stage	3	0.05	31.5	65.45
S.P. outlet	3.5	0.05	26	70.45
I.D.F inlet	4.1	0	24.5	71.36

The volume of gases passing through the exhaust fan I.D.F. = 3350 Nm^3 / min. which means that infiltrated extra air had dropped from 22% to 11% which equals a value of 310 Nm^3 / min.

Electrical and thermal energy saving value:

- Electrical Energy:

The specific rate of electrical energy consumption for the I.D. Fan decreased from 8.8 kWh/ ton to 7.9 kWh/tonne. This means that a decrease of 0.9 kWh/tonne was achieved calculating annual drop for producing 900,000 tonnes, for 0.04 J.D./kWh, so saving value equals (32,400) J.D. (equivalent to 46,000 dollars).

• Thermal Energy

The specific rate of thermal energy was reduced from 840 kcal/kg to 828 kcal / kg, which means a drop of 12 kcal / kg for producing 900,000 tons yearly, reducing daily consumed fuel by a value of 3.7 tonne fuel, which is 72,000 JD (or 103,000 US dollars). The total saving for both electrical and thermal energy was: 149,000 U.S. dollars.

6.9.2 Energy Consumption Utilisation for Cement Grinding

Rashadiya Factory / Jordan Cement Factories has four identical cement mills (A. B. C. D) in two lines. The technical specifications are as follows:

Technical Specifications:

- Number of mills	4
- Type of mills	two compartments tube mill in closed circuit (cyclone separator)
- Effective mill diameter	4.14 metres
- First compartment effective length	3.613 metres
- Second compartment effective length	8.515 metres
- First compartment charge ratio	29.2% (90,80,70,60 mm)
- First compartment charge weight	64 tonnes
- Second compartment charge weight	166 tonnes
- Second compartment charge ratio	31.1%
- Mill speed	15.43 rpm
- Rated power	3300 kW

- Mill feed size — clinker 80% minus 25 mm

  Gypsum 80% minus 40 mm
- Cement fineness — 3200 Cm^3 / g
- Approximate mixing ratio of gypsum — 4% of cement by weight
- Rated grinding capacity — 85 tonne / h.

Cement mill (D) was chosen to study the possibility of reducing electrical energy consumption in the grinding process, knowing that electrical energy consumption rate = 52 kWh/ton.

Average operational data for mill (D) during study period:

- Mill feed rate — 85 tonne / h
- Clinker feed rate — 81 tonne / h
- Gypsum feed rate — 4 tonne / h
- Specific power consumption — 40 kWh/tonne (mill drive)
- Mill drive power — 3350 kWh
- Bucket elevator power — 35 kWh
- Cyclone separator speed — 75 rpm
- Production return flow — 60 tonne / h
- Mill outlet gas pressure — 25 mbar
- Mill outlet material temperature — 110C
- Production fineness — 3170 Cm^2 / g
- Mill charge ratio — first compartment 29.2% second compartment 31.15%

Previous studies and operation data have proven that a noticeable decrease of electrical energy consumption can be achieved by means of reducing mill main drive motor consumption, as it consumes most of the electrical energy needed for grinding (77%). Average cement return flow, bucket elevator's electrical current, and cyclone separator speed were all too low due to the high percentage of iron balls in the mill. Iron balls are used for grinding and, as can be imagined, they are heavy, so moving them requires large quantities of energy. For that reason reducing the iron ball percentage (i.e. reducing their number or improving the degree of fineness of raw material) in the mill was essential in order to reduce energy consumption.

Experiments were carried out to improve the filling degree of the mill, and to achieve the required cement specification. The results were as follows:

- Ball charging for the first compartment was reduced from 29.2% to 26%, using iron balls of the same size:
- New filling degree 26%
- Total weight of ball charge 57 tonne
- Ball charge weight difference 7 tonne
- Ball charging for the second compartment was reduced from 31.1% to 27% with the same size of iron balls:
- New filling degree 27%
- Total weight of ball charge 144 tonne
- Ball charge difference 22 tonne
- Total reduction of ball charge 29 tonne

The results of the above experiments were as follows:

1. Mill production rate for 3360 working hours: 82.84 tonne /h.
2. Cement fineness rate for the same period: 3150 Cm^2/g.
3. Main drive specific power consumption for 3360 working hours: 3000 Kwh, achieving a drop of 350 kWh/h and electrical energy consumption reduced from 39.4 kWh/t to 35.3 Kwh/t, i.e. a *value of 4.1 kWh/t was saved.*
4. Iron ball wear rate did not change.

Electrical energy consumption saving value was about 7,254,000 Kwh, which equals 209,660 JD/year and 180,000 tonne/year of ground cement, which equals 414,000 US dollars.

6.9.3 Saving by Concentrating on Night Hours Operation:

Example: saving achieved by running cement mill/6, as a result of applying electrical load management policy.

Cement mills' consumption of electrical energy accounts for 41.32% of the total electrical energy consumed to produce one ton of cement, and unit productive capacity is higher than that of the previous and following production stages.

Therefore, the cement mills were programmed to run during night hours, when electricity is cheaper, and their running during the day-time was strictly not allowed, except in emergency cases. Beside this arrangement reduces the need to operate the cement mills during the peak load time, which will reduce the maximum load tariff.

The electrical energy consumption for cement mill /6 running during night hours, compared with total value of electrical energy consumed by cement mills 4,5,6 and 7 and the percentage of consumption can be seen in the following table (6.5).

Table (6.5)
Electricity Consumption of Mill 6 in Comparison with the Electricity Consumed by all Mills

Year	KWh consumed during night hours for mill/6	KWh consumed by all under working mills	Percentage
1985	692770	1528315	45.3%
1986	483230	1323540	36.5%
1987	319060	1276731	25%
1988	390570	1082730	36.1%
1989	378120	1005030	37.6%
1990	363945	1191470	30.5%
1991	394040	1272270	31%

Jordan Cement Factories, Fuhais Plant Annual Reports

It is concluded after the necessary calculations that the day hour's operation cost for cement mills 4,5,6, and 7 have decreased from 68,020 JD in 1987 to 9,911 JD in 1989, a saving of 58,109 JD.

6.9.4 *Wear of Roller Mill and its Effect on Electrical Energy*

Studies were made on wear of grinding rollers and dish segments of raw mill/6 in relation to specific electrical energy consumption.

The method of monitoring specific electrical energy consumption, for different factory units, is highly important for controlling the function of those units and detecting any deviation or difference in values, so that problems can be solved without delay. As an example, monthly monitoring of electrical energy consumption of raw mill/6 main drive was made concerning kWh/h and kWh/tonne, and wear of grinding rollers and segments of raw mill were monitored too. The conclusion derived by comparing these sets of data, was that specific electrical energy consumption is directly proportional to wear.

It is possible to run the raw mill without changing any segments for 11,000 working hours. After that, specific energy consumption will increase due to wearing. In 1989, extra cost due to the increase of energy consumption was 11,207 JD, which was more than the investment cost of replacement with a new segment.

6.9.5 *Calibrating Flap Gate of Cement Mill / 6 Circulation Fan:*

Calibrating the opening of circulation fan flap gate of raw mill/6:

Calibration and controlling the operation conditions:

The flap gates of circulation fans of cement mill / 6 were calibrated by reducing the percentage displacement of the opening from 100% to 50%. This resulted in reducing the speed and centrifugal force of the mill while maintaining fineness and operational conditions (such as mill filling, fineness, electrostatic precipitator flap gate, and

Pozzolana ratio, ... etc). Distribution of produced cement particles for both cases (100% and 50% flap gate opening) were tested during the experiment on a sieve of 1-322 micron using a laser Granulameter device. Consumption saving was monitored and found to give a value of about 362,762 Kwh, which is 1.75% of the total consumption of cement mill /6, during the year, costing about 12,080 JD The same results were achieved for cement mill/7. So total saving achieved in this case was 24,160 JD.

The following table (6.6) indicates operational conditions and the results in both cases.

Table (6.6)

Operating Conditions and Results

Item	Circulation fan opening 50%	Circulation fan opening 100%
Feeding (tonne/h)	184	182
Filling percentage %	92	92
Elec. eng. Consumed by mill	7.15	7.2
Cyclone sep. speed (Rev./min.)	305	465
Cyclone sep current (Amp)	245	496
Circulation fan opening (%)	45	100
Circulation fan current (Amp)	49	67
Clinker conveyors current (Amp)	143	132
Electrostatic Precipitator opening (%)	100	100
Pozzolana percentage (%)	16	16
Fineness (on brotle 36 micron)	4.6	4.4
Hardness of product cement (kg/m^2)	370	322

Jordan Cement Factories, Fuhais Plant Log Book and Log Sheets

6.9.6 Timing of Stopping Auxiliary Units

In order to maintain steady state operation of the mill, the auxiliary units run before the mill main drive and continue working, even after stopping the main drive for safe cool down period. That means auxiliary units work with no production, consuming electrical energy. Cement mills' auxiliary units are very high in consumption of electrical energy, accounting for 17-21% out of the total mill consumption according to the energy section information. For that reason the auxiliary unit operation should be managed properly so as to be started or stopped according to the necessary operational requirements.

6.10 Factors Affecting Energy Consumption

From the analysis presented in this chapter section 6.4 and some other sections, it can be clearly seen that there are many factors, which have direct (and indirect) effect on energy consumption. These factors include the following:

- Production rate
- Availability
- Number and duration of stoppages
- Operational efficiency
- Technology of processes
- Maintenance programmes
- Quality control and Inherent characteristics of raw materials (such as lime saturation factor, silica ratio, Alumina ratio and circulation phenomenon).

Some of these factors are interrelated or interlinked. Operational efficiency, for example, is related to plant availability, and also to maintenance programmes.

The case studies presented earlier in this chapter demonstrate that there is a certain effect on energy consumption (electrical and thermal) from most, if not all, of the factors mentioned above. However, the degree of relationship among any of these factors and energy consumption can only be determined through a statistical analysis model, although empirical evidence is available.

Therefore, the next chapter is devoted to the task of determining the statistical relationships among some of these factors and energy consumption. In other words, the relationships found empirically among energy consumption and some of the factors will be tested statistically using historical information to see if a valid statistical model can be developed explaining these relationships. Furthermore, this statistical model will be used to develop an economical model to verify and measure the economic gains resulting from energy management.

The selection of the factors to be studied within the statistical analysis depends on the results presented in this chapter, the judgement of the researcher, and the availability of reliable historical data. Naturally, there is a limitation to the amount of work to be included in the statistical model in order to have a meaningful explanation of relationships. Therefore, the most important factors will be selected for the statistical analysis in Chapter 7.

6.11 Conclusions

In this chapter an attempt was made to illustrate the importance of energy management to an energy-intensive industry, namely the cement industry in Jordan. The energy management issue was dealt with from different aspects, among them the Philosophy of the Energy Management. Factors and means of energy consumption control including the stability of the operational process, which affects the number of stoppages and therefore affects the level of energy consumption. The chapter ended by presenting the results of six practical case studies.

Preliminary detailed empirical analysis of the main factors affecting energy consumption was carried out in this chapter. These factors include availability, production rate, number and duration of stoppages and factors affecting quality of produced cement.

In essence, this chapter shows, in a clear manner, that the application of energy management tools within an EMS is not only possible but also beneficial. The case studies carried out by the factory staff under the supervision of the researcher provided both qualitative and quantitative evidence of this. However, a detailed statistical and economical analysis to define the relationship between energy consumption and the control factors is needed which will be covered in Chapter 7.

The preliminary empirical results obtained in this chapter and the qualitative and quantitative evidence resulting from the case studies illustrate, beyond doubt, the vital need for establishing a detailed Energy Management System (EMS), which will be presented in Chapter 8.

Figure (6.1) Energy Consumption Control Diagram

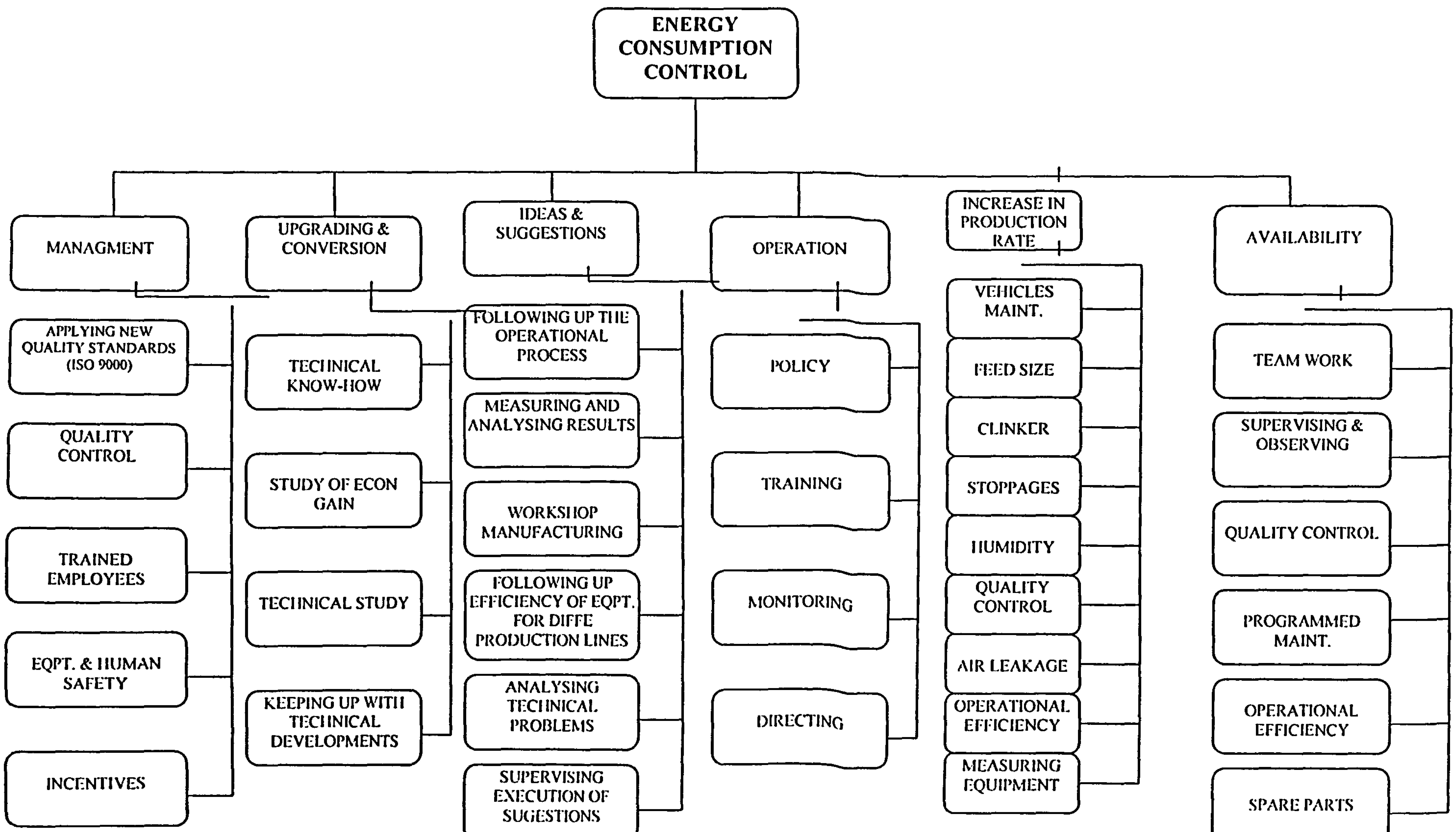
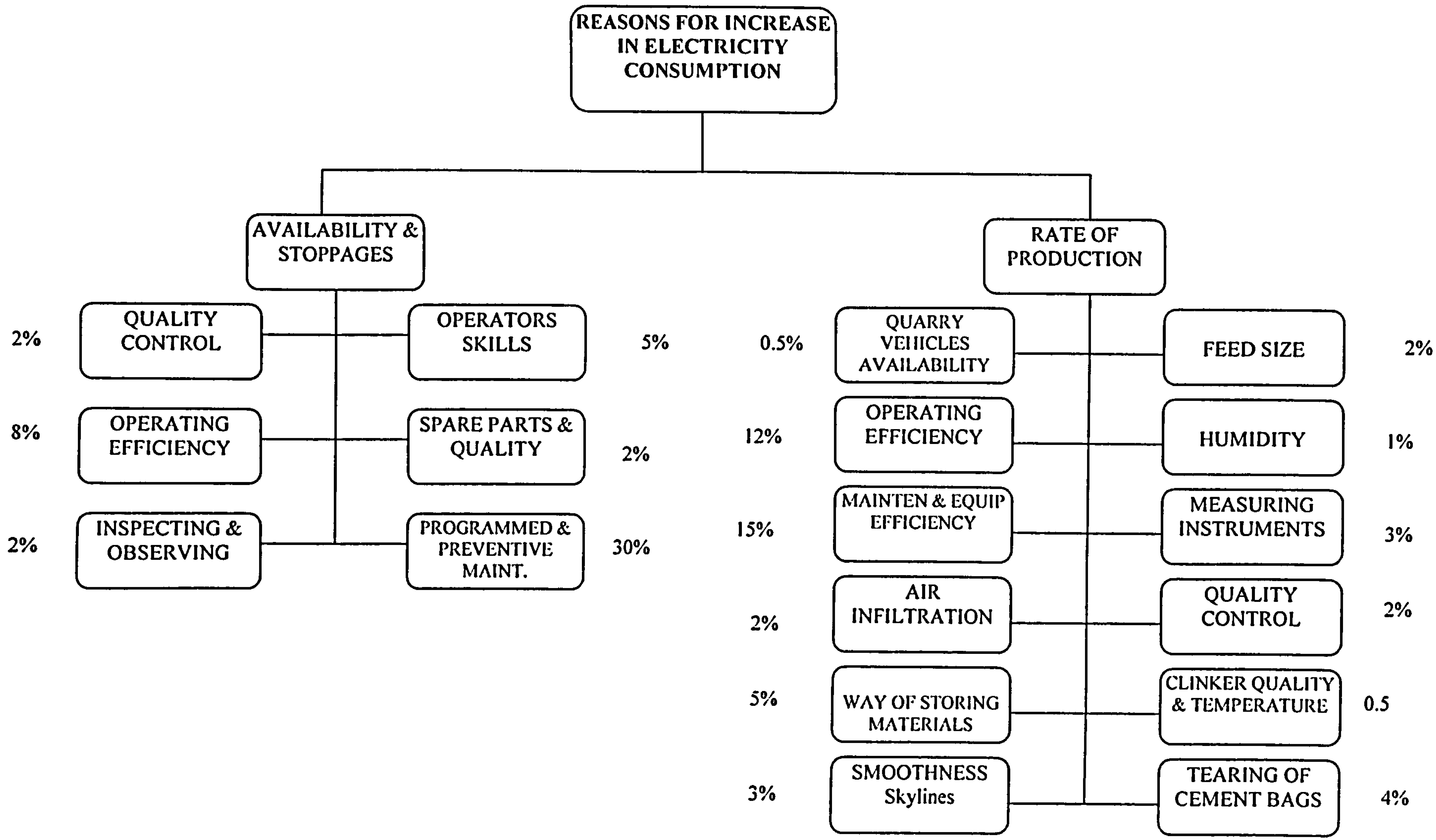
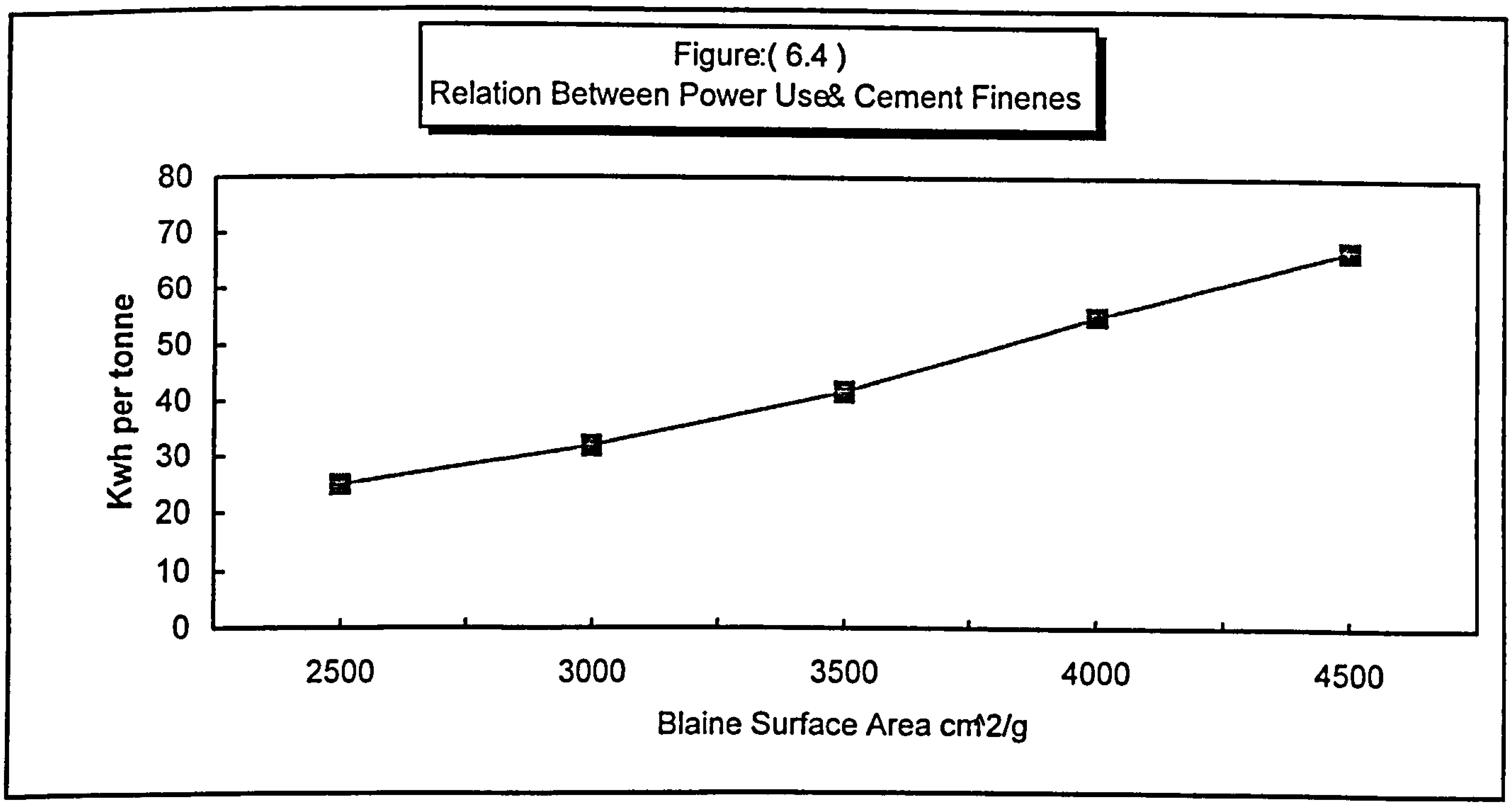


Figure (6.2) FUEL Consumption Factors

Figure (6.3) Electricity Consumption Factors

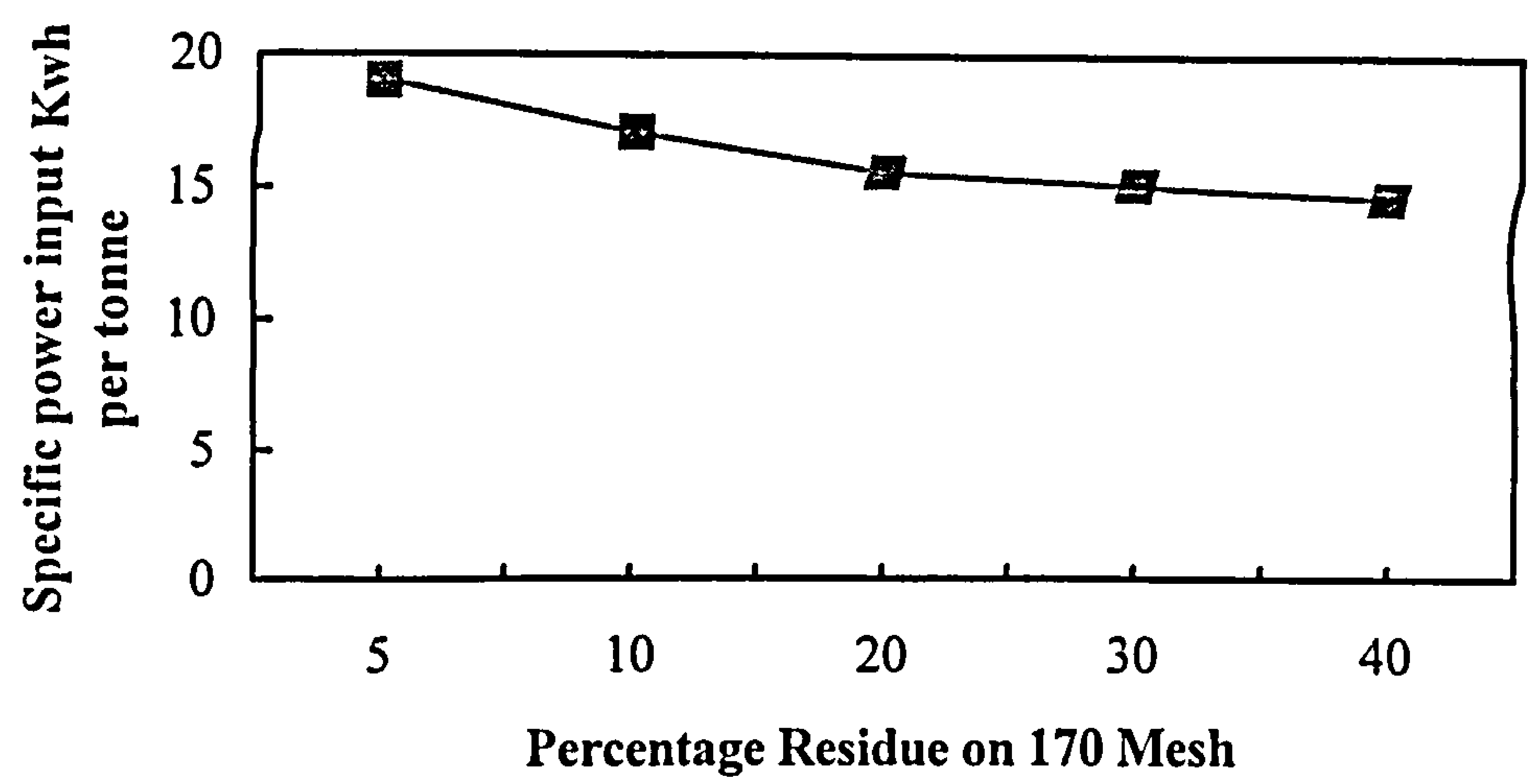




Source: Holderbank Cement Seminar 1997 (simplified)

Figure:(6.5)

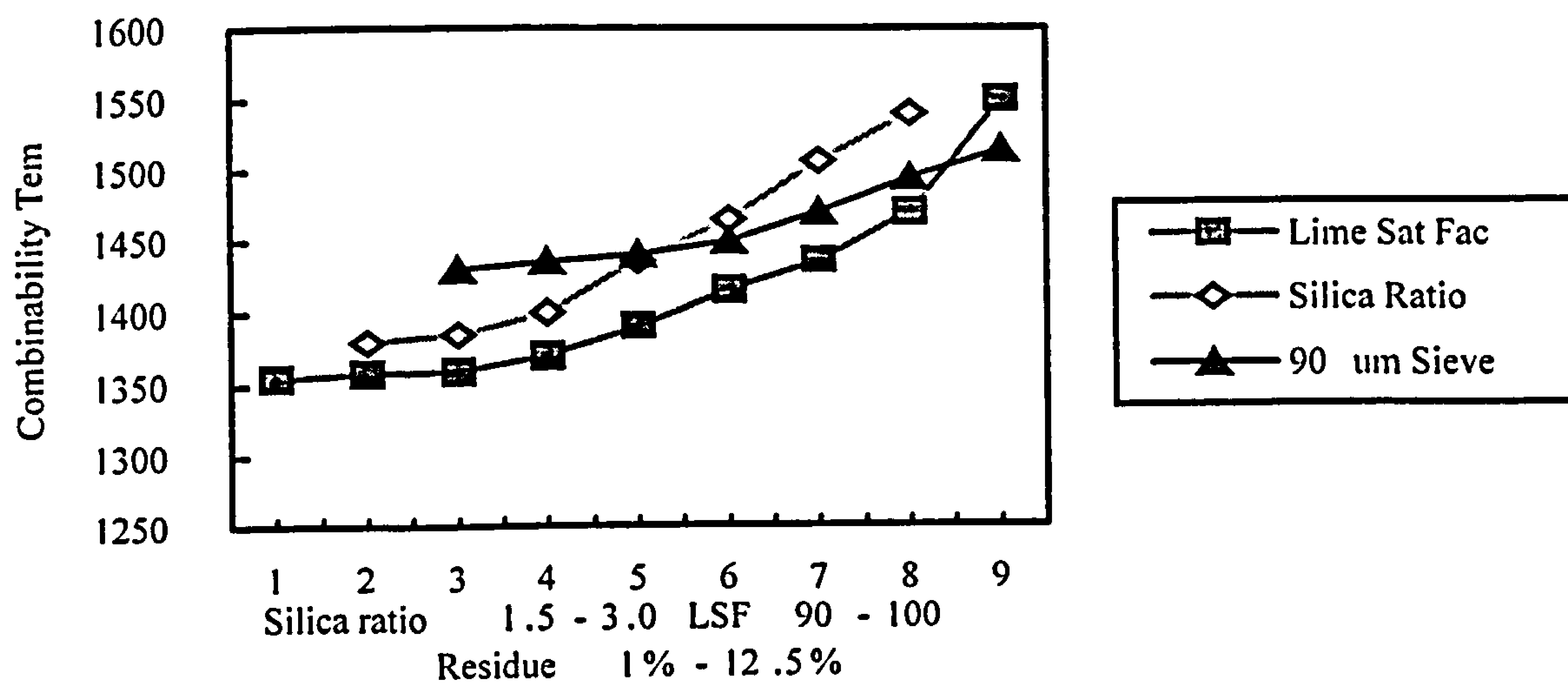
Relationship of Raw Meal Fineness & Raw Mill Power Use



Source: Duda 1977, (simplified)

Note: residue is inversely proportional with fineness

Figure : (.6.6)
Effect Of LSF , Silica Ratio & Residue on Combinability Temp



Source: Blue Circle Cement Seminar 1979, Vol. 1

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