

THE ANALYSIS OF THE ENERGY ECONOMY OF

SOUTH AFRICA

WITH SPECIAL REFERENCE TO ITS FORECASTING

BY

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PREFACE

In a modern economy nearly 20 per cent of the total development outlay is normally accounted for by the energy industry. It would therefore appear imperative that developing countries make appropriate administrative arrangements for the systematic collection, compilation and, where necessary, dissemination of all the relevant data on the different branches of this industry.

Yet in South Africa, so far, very little has been done in the field of energy research, both officially and by private researchers. The reasons for this state of affairs are perhaps not too obscure. Firstly, the analysis of the energy economy is a complex and difficult task. The procedures and disciplines developed internationally for throwing light on the structure of the energy economy and its forecasting, are largely still in the evolutionary stage. All too frequently the strategy here has been one of sitting on the sidelines while others conduct the expensive research.

Secondly, the efforts of local research workers who have attempted to throw light on the South African energy situation have almost always been thwarted by a complete lack of sufficiently reliable and detailed statistics. This is possibly why available works on the subject are of a descriptive rather than analytical nature. While the importance of adequate data for analysing the energy economy has been recognised by most countries in Europe and North America and while most of these countries collate and publish the relevant data on a regular basis, the practice is still sadly lacking in South Africa. In quite a few countries abroad government sponsored bodies, agencies or organisations also conduct full time research on various aspects of the energy situations in their respective countries; the results of which normally form the basis of the energy policies in those countries. It is in fact the experience in these countries that the task must essentially be tackled

by a team of specialists, including economists, econometricians, engineers, physicists and forecasters. It is indeed a colossal assignment for one research worker alone.

Lastly, until recently, the popular belief that South Africa possesses virtually inexhaustible supplies of energy, in the form of coal, has possibly given rise to the low priority afforded to the examination of the energy problem here. In many other countries factors such as dwindling indigenous supplies of energy and the consequent strain on the balance of payments, coupled with insecurity of supply from abroad, have necessitated an early evaluation of all the possible options. Recent developments in South Africa have seriously invalidated the contention of unlimited energy supplies and a new assessment appears to be necessary and desirable.

Within the South African context, therefore, the analysis of the energy economy should be categorised within the following three broad problem areas:

1. The understanding of the complexity of the energy economy, its operation and its interdependence with the general economy. This will aid the simulation and quantification of the operation of the energy economy in order to provide a basis for forecasting and, therefore, for future planning.
2. The systematic collection of all the relevant data and information which are necessary for a satisfactory analysis and forecast of the energy economy. As the emphasis in work of this nature is normally directed at medium to long term planning, the required data will usually take the form of time series over a fairly long span of time.

3. The examination of the current state of forecasting technology, the selection of available tools or techniques and their adaptation compatible with the requirements of such an analysis of the energy economy.

The purpose, scope and layout of this study are in accordance with these stated objectives. Part I deals with the methodological problems of analysing the energy economy and the collection and presentation of data associated with such analyses. Part II deals with the forecasting problem, its methodological aspects and its application to the South African energy economy.

Part one is divided into three chapters. The first chapter covers the identification and examination of the various methods of analysing the energy economy. In chapter two the individual energy and allied industries in South Africa are analysed, while the third chapter deals with the construction of the actual energy balances of South Africa.

Part two is also divided into three chapters. In the fourth chapter the examination of the forecasting problem and its methodological aspects are studied, while in the fifth chapter a forecast is attempted of the future course of the South African energy economy. In the sixth and last chapter the implications and findings of the study, both in terms of the forecast and methodological considerations are examined, and recommendations discussed.

D.J.K.

OCTOBER, 1970.

THE ANALYSIS OF THE ENERGY ECONOMY OF SOUTH AFRICA

WITH SPECIAL REFERENCE TO ITS FORECASTING

PART I THE ENERGY ECONOMY - METHODOLOGY AND DATA

- Chapter 1 The Analysis of the Energy Economy - The Methodological Problem
- Chapter 2 The Energy and Allied Industries of South Africa
- Chapter 3 The Historical Energy Balances of South Africa

PART II FORECASTING OF THE ENERGY ECONOMY

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PART I

THE ENERGY ECONOMY - METHODOLOGY AND DATA

CHAPTER I

THE ANALYSIS OF THE ENERGY ECONOMY - THE METHODOLOGICAL PROBLEM

1.1 Introduction

The history of the social and material advance of man stands in direct relation to his ability to control energy. The growth of man's dominion over matter is indeed a long drawn out process which extends back through history and prehistory, to the very beginnings of humanity. Every important technical advance, such as the use of tools to redirect human effort to better advantage, control over fire or control over the energy of horses and other power animals, has involved some new phase in the control of energy. Today, man's struggle for dominion over matter still continues.

One feature of prehistory is that there is no evidence that man has ever been without knowledge of fire. Sumner and Keller state that "Over the whole earth there is no fireless tribe of man man is scarcely man until he is in possession of fire."¹⁷ It may well be that fire, once man had put it to his use, was the chief instrument of his supremacy in the animal world. In glacial times, when man took to the caves, so did the bears and the lions; but fire protected man. While man sought food the fires had to be tended.

As long as man was dependent on his own strength, his own energy output, to feed and comfort himself he had to remain a total savage. To attain civilization he had to satisfy the prerequisite of leisure - he had to acquire time for thought and contemplation. And this could be bought only by the use of energy beyond that which the individual could produce. He had to find ways of utilizing the energy produced by fire, animals and slaves.

From man's beginnings and up to about 1700 A.D., practically all the motive power used for purposes of peace or war was supplied by man or animals. The conquest of animate energy goes back to 4000 B.C. - the first representation existing of man riding horse.²⁷ It is also known that the inhabitants of Mesopotamia had used wheeled vehicles by 3500 B.C. and, according to Arab writers, wind energy was utilized by Persian wind-mills by about 900 A.D.

As late as the twelfth century, a significant increase in the available leisure time of mankind occurred with the invention of an efficient method of harnessing the horse.³⁷

Real progress in productivity came with the beginning of the development of mechanical energy - the conversion of heat into kinetic energy by Watt and Stevenson, which ushered in the Industrial Revolution in Britain, approximately two hundred years ago. The Industrial Revolution marks the watershed between two energy ages - the age of predominant dependence upon animate energy and the age of inanimate energy derived mainly from fossil fuels. Energy consumption changed not only in degree but also in kind. Previously the sources of energy were being continually replaced, but, from the time when man's living became dependent on fossil fuels, he was living on finite energy resources which were bound one day to be exhausted.

A hundred years ago, heat, and the power provided by it, was a mystery. Man then generalised his experience of natural behaviour by formulating the laws of thermodynamics and his conception of energy; it was one of his supreme achievements. The conception of energy and the laws governing its transformations are intrinsic in the tremendous structure of scientific knowledge which has since been built up.

The history of energy sources is characterised by the constant replacement of one energy source by another; new and better fuels have come into use before resources of existing fuels were depleted. Over the years, wood

lost its predominant position to coal. Coal was the fuel of the Industrial Revolution, but the consummation of that revolution required a whole range of fuels, each manufactured to critical specifications.

Such fuels were made possible by the development of the oil industry in the latter half of the 19th century. Consequently from 1900 onwards the consumption of oil has been mounting in a steep curve. The reasons for this rapid rise in consumption of petroleum fuels are not hard to see. The internal combustion engine, which literally put the world on wheels, would have made little headway but for the fuels and lubricants developed by the oil industry. In fact, it would not be an exaggeration to say that the development of the petroleum industry in the last hundred years has acted as the biggest single agent in the transformation of the world.^{4/}

Today man is living in the Second Age. Indeed in one respect the distinction between advanced and underdeveloped countries can be drawn in terms of the extent to which they are still in the first stage of animate energy or have progressed to the second stage of inanimate energy utilization.^{5/}

The age of animate energy consumption extended over thousands of years. By contrast, the age of inanimate energy is only about two hundred years old. About seventy years ago, the convertibility of matter and energy first came to be envisaged when Einstein developed his famous equation $E = MC^2$. In 1942, Enrico Fermi and his co-workers succeeded in achieving this conversion and man entered the era of nuclear energy.^{6/}

The third age of energy man can look forward to is one in which he may be released from dependence upon finite fuel resources. Among these future sources of power may number nuclear fusion, wind energy, tidal energy, volcanic energy and solar energy.

Until quite recent times, all the energy used by man was derived from the sun. It was no wonder that man was a sun worshipper. The sun radiates enormous quantities of energy of which only a two-thousand-millionth part reaches the earth. The energy for man to draw upon is there in abundance.

1.2 Energy - definitions, sources and forms

Energy is associated with action or the possibility of action; it provides the power¹⁾ to perform work. It exists in various guises - thermal, electrical and mechanical. It can be transformed.

1) Power, as defined in scientific technology, is work performed in unit time, i.e. joules per second:

Force = Mass x Acceleration. Force is measured in dynes.

The dyne is the force which, if applied to the Standard gram body, would give that body an acceleration of 1 centimeter per second per second. (The "Standard Kilogram Body" refers to a material standard of mass, carefully preserved at Paris.)⁷⁷

Work = Force x Distance. Work is measured in ergs, e.g.,
1 erg = 1 dyne x 1 cm., and,
1 joule = 10^7 erg.

Energy is therefore the ability to do work. The units by which it is measured are called the erg and the joule.

Power is the time rate of transferring or transforming energy. The practical unit of power is the watt.

1 watt = 1 joule per second = 10^7 erg per second.

One kilowatt hour, therefore, equals 3.6×10^6 joules.

Energy-producing agents contain energy in some potential form or another: chemical energy in fuels; heat in steam; mechanical energy in a quantity of water at a height or in air in motion (wind energy). Other forms of energy, on the other hand, are not tied to a material vehicle. Examples are electrical energy, and, in some cases, mechanical energy, which constitute forms intermediate between other forms of energy and are merely transmitted by a material medium. Lastly, there is energy in the form of electro - magnetic radiation, such as light, which does not depend on matter, either as a vehicle or for its transmission.

Energy-producing agents can be classified into commercial or non-commercial sources of energy, in accordance with the definitions used by the Statistical Office of the United Nations.^{8/}

Commercial sources of energy include anthracite, bituminous coal, pitch coal, brown coal, lignite; petroleum, shale oil, natural gasoline, natural gas and electricity.

Non-commercial sources of energy include peat, bagasse¹⁾, fuel wood, lumbermill wastes and other fuels that are largely of local significance such as dung, straw, paddy husk and other wood and agricultural wastes.

Although the consumption of non-commercial sources of energy is normally excluded from the systematic analysis of the energy economy, in a number of countries these sources represent a very significant part of the total. It has been estimated that the percentage of non-commercial energy used in various regions out of the total energy consumption is as follows:-^{10/}

1) Bagasse, the fibre content of the sugarcane after the juice has been extracted, is widely used in paper making for which purpose the pith (the lower density heart), is first removed. Fuel may thus comprise the complete bagasse, if no paper making exists, or the pith alone.^{9/}

Asia	56%	Soviet Union	14%
Africa	48%	Oceania	12%
South America	48%	Europe (excluding Soviet Union)	7%
Central America	36%	North America	4%

Consumption of these sources are normally more preponderant in the underdeveloped world. In a careful study of India's energy consumption in 1959, for instance, it was found that non-commercial fuels (excluding animal power), accounted for about 70 per cent of the country's total energy supply.^{11/} Almost all the non-commercial fuels were consumed in households. With the growth of economic and social development, non-commercial forms of energy are gradually replaced by commercial energy. For example, it is reported that 94 per cent of energy consumed in the United States in 1800 consisted of wood fuel and that this percentage was as high as 28 per cent even in 1900, as against only 4 per cent or less at present.^{12/}

In South Africa it may be expected that significant quantities of non-commercial fuel have been, and are being consumed by, especially the less developed ethnic groups in the underdeveloped areas of the country. Here however, the problem exists, as elsewhere in the world, that a precise estimate of past and present consumption is not available and is obviously very difficult to arrive at.

It can also be inferred with a reasonable degree of certainty that part of the increased commercial energy consumption in recent years, particularly in the domestic and non-industrial sectors, has been the result of conversion from non-commercial to commercial sources. Similarly, lack of data preclude an estimate of the rate at which such replacement has taken place. Consequently, because of these difficulties, the consumption of non-commercial sources of energy in South Africa will be excluded from this study.

1.3 Forms of energy

An analysis of the energy economy cannot include all the forms in which energy occurs and all the forms in which it is finally consumed. Consequently the analysis is restricted to those forms of primary and secondary energy which really play a part of some significance in the energy economy.

1.3.1 Forms of primary energy

The term "primary energy" is applied to the energy content of the energy-producing agents occurring in nature: coal, lignite, peat, wood, crude petroleum, natural gas, hydraulic power, geothermal power, wind energy, solar energy and nuclear energy. Because they are quite insignificant, however, wind energy and solar energy are generally omitted from the analysis, while such sources as fuelwood and peat, on the other hand, may be of some importance, for example, in countries such as Austria, Scotland, Denmark and Switzerland. It follows that the list of forms of energy taken into account in the analysis may vary according to the economy of the country or region being considered.

In some countries, the possibility of taking animal and human labour into account has been considered. But, although these are certainly special forms of energy, they are of no practical significance in the energy market and are thus outside the sphere of the energy economy. Moreover, they are really secondary forms of energy derived from the conversion of the energy contained in food stuffs, which understandably belong to the spheres of agriculture and the food products industry. Hence, human and animal labour can justifiably be omitted from an analysis of the energy economy. The economic importance of the replacement of human and animal energy by energy from commercial sources is reflected in the resultant higher productivity.

Hydraulic power is generally used in the form of electricity; consequently the electrical energy produced by hydro power plants is usually regarded as primary energy. In some countries, however, hydraulic power is regarded as primary energy, and its quantity is determined from the hydro-electric energy produced and the average efficiency of the hydro power plants.¹³⁷

A similar problem arises in the case of geothermal energy, which, in Italy for example, is almost entirely converted into electricity. In such cases, the electricity produced is regarded as primary energy. If, on the other hand, the geothermal energy is used as a source of heat, as it is in Iceland, for example, it seems more correct to consider its heat content as primary energy.

The introduction of nuclear energy into the energy economy raises a new problem. Some experts take the view that, pending future development in this new field, electrical energy produced by nuclear power plants should be regarded as primary energy.¹³⁷ Since nuclear energy is also used for purely thermal purposes, however, it seems more correct to consider the nuclear power plant as a thermal plant consuming nuclear fuel, and the electrical energy it produces as secondary energy. Uranium and thorium would then have to be regarded as sources of primary energy.

The easiest way to take account of nuclear energy would be to record among the primary forms of energy the net quantity of electrical energy (and perhaps of heat also), produced by nuclear installations. This simple method may be all that is needed so long as nuclear energy continues to account for only a modest part of total energy consumption. Later on, it will be necessary to make separate provision for uranium and thorium and for the fissile materials produced by irradiation. The operation of nuclear power plants would then have to be considered in the analysis of commercial conversions of energy.

Forms of primary energy are also classified according to exhaustible and inexhaustible primary energy sources. Exhaustible primary energy sources occur in nature in solid, liquid or gaseous forms such as coal, peat, wood, oil, natural gas, all different types of fossil fuel, as well as uranium and thorium, the present usable nuclear fuels.^{14/} Among this group, coal and oil represent the world's most important sources of primary energy, and are converted mainly by the chemical and electrical industries into different forms of secondary energy. The most important characteristics of exhaustible energy sources are that they occur in nature in finite quantities and that their reserves are steadily being depleted and cannot be replaced.

Among inexhaustible sources of primary energy number hydraulic energy, solar energy, tidal energy, wind energy and geothermal energy. The single most important characteristic of sources of energy of this nature is that its exploitation is limited to availability in both space and time. Its potential, however, cannot be depleted.

1.3.2 Forms of secondary energy

"Secondary energy" is generally understood to mean the forms of energy resulting from one or more conversions of forms of primary energy, excluding, however, the forms resulting from the last conversion carried out by the final consumer, which are distinguished by the term "useful energy".

Energy is, as a rule, commercially converted in a plant specially designed for the purpose, such as an electric power station, a coke-oven plant, a gas works, or a petroleum refinery. Blast furnaces are usually included in such an enumeration, because although they are built primarily for the production of pig iron, they produce large quantities of gas as well.

Some energy-producing agents are used by industry for the manufacture of explosives, calcium carbide, welding gas and other products containing certain quantities of energy. Although they are used to produce certain forms of energy under special conditions, they are unimportant from the

point of view of the energy market. For this reason they are not regarded as secondary forms of energy, and are disregarded in the energy economy.

Lastly, there are certain by-products of energy conversion processes which contain quantities of energy but are rarely used for the production of useful energy. Examples are asphalt, a by-product of the petroleum industry, and tar and pitch, by-products of the gas industry. The economic value of such products is determined mainly by their use for purposes other than energy production. Hence, they are not offered on the energy market, and their significance in the energy economy is theoretically limited to the influence of the proceeds of their sale on the cost of the energy agents produced by the conversion process in question. These products should, therefore, properly be regarded as non-energy-producing by-products, and are excluded from the forms of secondary energy.

1.3.3 Tertiary, quaternary and diverse intermediary forms of energy

In some countries a distinction is made between secondary, tertiary and quaternary energy, according to the number of conversion processes. Breeder reactor fuels, such as plutonium and ^{233}U , could also possibly be regarded as tertiary forms of energy.^{14/}

Generally speaking, this distinction is only theoretical, for one cannot tell from the form which the energy takes after its last conversion how many conversions were carried out during its production. Accordingly, it seems unnecessary to maintain this distinction.^{13/}

1.3.4 Forms of useful energy

Energy consumed usefully after its last conversion by the final consumer is known as "useful energy". This energy is produced by the conversion appliance used by the final consumer and consists of the heat produced by a stove, the mechanical energy supplied by a motor and the light given off by a lamp.

Four different forms of useful energy are usually distinguished, namely, heat, mechanical energy, chemical energy and light. They are not generally subject to commercial transactions except in the case of electrolysis, where the electrical energy consumed is itself a form of useful energy. The consumption of thermal, mechanical, chemical and luminous energy thus no longer belongs directly to the energy market.

It is the requirements of useful energy, however, which determine the demand for energy on the energy market, and for the purpose of studying the characteristic factors governing competition, and therefore, substitution, it is necessary to take account of the quantities of useful energy consumed. For it is the trends in the development of this consumption which lead to development as a whole in the field of the energy economy. In practice, however, it is normally very difficult to determine the exact consumption of useful energy, principally because of the lack both of statistics, which make it possible to distinguish the quantities of useful energy consumed, and of precise data concerning the efficiency of the processes of conversion into useful energy.

1.4 The energy economy

The energy economy is the economic activity concerned with the production of the primary energy producing agents, their industrial conversion into secondary forms of energy, the import and export of different forms of energy, and their transport up to delivery to the final consumer.¹³⁷

The final consumer rarely uses the energy in the form in which it is supplied; he usually carries out a final conversion into the form of useful energy he requires: heat, mechanical energy, or light.

In different countries the energy economy has a varying degree of importance vis-à-vis the national income. But energy is among the essential basic needs of all industrial activity and transport, and is a very important factor in agricultural production, trade and family life.

Hence the importance of providing a regular supply of energy at low cost, while leaving consumers free to choose the form of energy that suits them best.

The consumer has a choice between several forms of energy for final conversion into the useful energy he needs. If, for example, he needs heat, he can, in theory, use any of the forms of energy on the market. For mechanical energy his choice is more limited, while for lighting, electricity is almost the only adequate source.

It is considerations of cost, reliability of supplies, ease of transport, necessity (or otherwise) of keeping stocks, and convenience in use which determine the consumer's choice. It is these considerations which finally determine the consumption of the different forms of energy offered on the energy market, and which underlie all development in the field of the energy economy. Thus the general aim of an analysis of the energy situation is to establish the trends of this development, and more particularly to take them into account when endeavouring to provide a regular supply of energy at fair prices, in quantities and qualities that satisfy demand.

1.5 The underlying objectives of an analysis of the energy economy

The energy economy is normally analysed for many specific reasons or objectives. The analysis itself remains substantially the same, except for minor modifications in detail required, and the emphasis placed on particular aspects depending upon the purpose for which it is intended. These objectives can be generally classified under the following four major headings:

- (i) the determination of the structure of the energy economy
- (ii) the forecasting of energy demand
- (iii) the formulation of national or regional energy plans and policies, and
- (iv) special studies.

1.5.1 Structure of the energy economy and energy market

The main object of analytical studies of the energy economy is to investigate its structure, which is very complex. The energy needed to meet a country's needs is produced from several indigenous sources of different primary forms of energy, supplemented by imports of the same, and other forms, of primary and secondary energy.

Although certain quantities of primary energy are supplied to the final consumers direct, large quantities are converted into a secondary form in processing plants before being absorbed by the final consumers. This is because of the advantages offered by the secondary forms as regards transport, convenience in handling and use, and efficiency of conversion into useful energy.

The different forms of primary and secondary energy are offered on the energy market. But each of the useful forms resulting from final conversion by the consumer determines, in principle, a partial energy market within which different forms of energy may replace each other. The competition between the different energy-producing agents on this partial market is governed by:

- (i) the price relationship between the different forms of energy
- (ii) the efficiency of final conversion
- (iii) the capital invested in the consuming plant, and
- (iv) the cost of operating that plant.

A study of the structure of the energy economy thus calls for an analysis of that economy which will make it possible to establish the extremely complex relationships between the various primary and secondary forms of energy, and to assess their importance and their influence on the trend of the energy market.

In addition to these economic factors, the following considerations also play an important part in the final consumer's choice:

- (i) habits formed
- (ii) convenience of use, and
- (iii) dependability of supplies.

1.5.2 Forecasting energy demand

The energy economy is also analysed within the framework of a study of its development trends, with a view to making short-term and long-term forecasts. It is sought to determine, for a period in the near or more distant future, the total energy requirements of final consumers, the shares of the various forms of energy in those requirements and the resultant primary energy requirements, as distributed among the energy-producing agents.

The forecasting of energy requirements for final consumption is rendered particularly difficult by the fact that their trend depends on the following three factors:

- (i) the trend of useful energy requirements in the various consumption sectors and new uses
- (ii) the trend of final conversion efficiency, and
- (iii) tendencies to substitute one form of energy for another.

While the first of the three factors is certainly related to the general trend of the economy and depends to some extent on price movements in the energy market, the second depends rather on technical developments, whereas substitution tendencies depend on:

- (i) revolutionary technological changes in the consuming sectors themselves or in the transportation of energy¹⁵⁷
- (ii) a rise in the standard of living leading to the introduction of more convenient, or even automated, systems of conversion into useful energy, and

- (iii) changes in the relationships between the prices of different forms of energy in the energy market.

Other indirect factors could be added, such as:

- (iv) the national economic situation
- (v) the availability of capital, and
- (vi) interest rates.

Furthermore, the primary energy requirements resulting from the needs of the final consumers depend on the technical and economic development of the industry producing the various primary energy agents and of the industry which converts the primary energy into various forms of secondary energy.

Hence, the forecasting of energy requirements for the near or more distant future calls for a thorough analysis of the energy economy to determine all these trends.

1.5.3 Formulation of energy plans and policies

The provision of energy is not only one of the most important prerequisites of economic growth, but is also a function of it. If the level of, nature of, or distribution of investment in, energy of all forms is inadequate, general economic expansion can be severely restricted or its pattern distorted. Other factors of production cannot be used to capacity, and excess demand on resources brings interruptions to supply, and frequently results in the breakdown of overloaded equipment.

On the other hand, the energy industries are very capital intensive and even a slight margin of excess capacity in supply may necessitate tying-up scarce capital at considerable cost to the economy as a whole and deferring other urgently needed investments. In order to ensure the most rational utilization of scarce resources, energy investment programmes have to be geared extremely closely to general economic expansion, not only in the phasing of the investment, but in its geographical

distribution and in its distribution between energy forms. And, because of the considerable time needed between planning and completion of major schemes, a country's energy plan or programme needs to be planned further ahead and in more detail than general economic expansion plans.

With rapidly growing demands for energy, governments should ensure that resources are adequate to meet them. There are, however, various ways of meeting these demands and governments' energy policies are concerned with achieving the right balance between different and sometimes conflicting objectives.

Energy policy has an important part to play in securing the major economic objectives of steady economic growth, full employment, stability of prices and a satisfactory balance of payments. In this light, the two principal objectives of energy policy can be defined as:

- (i) the assurance of adequate and reasonably secure supplies of the various forms of energy needed to sustain economic growth, and
- (ii) the assurance of reasonable energy prices, and the encouragement of reductions in cost of energy to the community as a whole and to the individual consumer.¹⁶⁷

Energy policies vary from country to country depending on its unique circumstances. Normally, however, the following six major elements of energy policy can clearly be discerned:

(i) Adequacy of energy supplies

Once the extent of local resources, as well as projected future demands, have been ascertained, it becomes necessary for a particular country to adopt strategies relating to the retrenchment or otherwise of indigenous energy industries that are having trouble in competing with imported sources. It may well be that a degree of conservation may be contemplated in order to prevent early exhaustion of reserves, should this be considered the best way of meeting the nation's energy requirements.

Ideally, in the long-term, either indigenous industry must be competitive or else resources should be transferred to where they can be more productive. At the same time, the overall objective of maintaining competition in all phases of the industry and providing a range of choices to the consumer should be a guiding principle.

(ii) Security of supplies

Most countries are committed to policies which are directed at the provision of energy supplies at the lowest possible cost. This is imperative in order to make a country's goods more competitive for exports or import substitution. A realistic balance between prices and security of supplies has to be struck, however, in view of the uncertainty of supply surrounding some imported sources, notably oil, seen within the context of its international availability.

(iii) Cheap energy

Subject to these overriding considerations of adequacy and security of supply, a governments basic objective can be summarised as cheap energy.^{17/} It does not imply that fuel prices should be held artificially low compared with real costs since this would lead to waste of resources. What is important is that full advantage of the cheapness and technical merit should be taken of potential or new sources, such as nuclear power, natural gas, etc.

(iv) Balance of payments, capital investment and use of resources

Except where the bulk of a country's requirements have to be imported, energy forms the most important single part of any industrial development programme, and, even where extensive recourse to imports is anticipated, careful study is needed in order to assess and minimise future cost to the balance of payments.

The first step must be to determine how much energy will be needed over, say, the next ten to fifteen years, when exactly it will be needed, where, and in what forms. While for many end-uses different forms of energy are interchangeable, there are certain uses for which the use of oil is virtually mandatory - e.g. road transport - others where electricity alone is practicable - e.g. lighting - and others where coal enjoys considerable advantages, for instance, in blast furnaces. So what is needed is an assessment of the amounts of future energy requirements which would, in effect, be earmarked to different fuels, and the amounts which could reasonably readily be supplied by a variety of energy forms.

On the one hand such a study is dependent on a country's general development plan or prospects. And on the other hand, it conditions these - since the resources to be directed to investment in energy will naturally affect the resources available for other forms of capital spending. Hence this study comprises, in fact, an assessment of priorities and of the relationships of the principal factors in development, such as transport, education, agricultural improvement, industrial facilities and the like. The requirements of the economy at the time and in the future - short, medium and long-term - need to be assessed against the resources available, in order that a rational choice of the options available should be made.

(v) Technology

Scientific and technological advance are vital in the energy sector, as elsewhere in the economy, in order to increase efficiency and reduce costs. In addition to serving their own internal efficiency, the fuel industries are able to contribute substantially to the promotion of technological progress in other industries, as purchasers of new equipment and as suppliers of raw materials. Much may be expected of the expansion of nuclear

power as a spur to the wide range of engineering industries involved in research and development, as well as to other branches of science.

Governments' actions, within the limits set by the size and form of the world's natural resources, are responsible for the overall climate in which the energy sector, both public and private, develops. An adequate supply of energy remains the prime responsibility of the energy industries, but governments have extensive power and a wide range of instruments to influence the development of the energy sector. It follows that governments are responsible for formulating and implementing a comprehensive and coherent policy. In particular, the need is to replace short-term palliatives by flexible long-term planning and to prevent short-term measures from prejudicing the achievement of long-term objectives.¹⁶⁷

1.5.4 Special studies

An analysis of the energy economy is sometimes made for special studies.

Countries possessing large deposits of a single energy source, such as coal or oil, have undertaken studies to gain a fuller knowledge of its uses in the various consumption sectors.

Other special studies of this kind may be directed towards establishing equilibrium between the coal market and the petroleum products market, or between indigenous and imported sources of energy.

Lastly, many different types of organisation are critically affected by the demand for or supply of, and prices of, fuel and energy in all forms. They include:

- (i) producers of all forms of energy, whether national or international in nature, or whether publicly or privately owned.

- (ii) government departments, planning organisations and other public authorities.
- (iii) producers of equipment used in the production of fuels and energy, and in the transmission of energy.

1.6 The energy balance sheet

The method of analysis most widely applied to the energy economy consists in drawing up an energy balance sheet. It has been indicated that the general purpose of analysing the energy economy is to reveal the problems involved in balancing the energy resources and needs of a country or region. The purpose of the energy balance sheet is to make this comparison of total availabilities and total consumption of all the energy-producing agents which play a part in the energy economy. Such a comparison is complicated by the fact that account has to be taken of a large number of different energy-producing agents, which are interchangeable and conditioned by the overall situation in the energy market.

It is this interdependence, in particular, that is not clearly shown by a series of partial balance sheets (one for each form of energy), when one form of energy is considered in isolation. Consequently, the need to study the interdependence between forms of energy has led to an attempt to draw up energy balance sheets in which the quantities of the different forms of energy that play a part in the energy economy are expressed in a common unit.

Such a balance sheet would show the total energy availabilities and requirements for a country, and also the shares of the different forms of energy in those availabilities and requirements.

The drawing up of energy balance sheets raises a number of problems, the solution of which generally depends on the object in view. The main problem arises from the unequal economic value of the different forms of energy. That value depends on the energy content and the form taken by the energy, for the form determines the yield in useful energy which the final consumer can obtain. In principle, therefore, it is impossible to express the different forms of energy in the same terms in order to add them together. Only one characteristic can be added at a time, for example, the energy content.

Another difficulty involved in drawing up an overall energy balance sheet is that it suggests that every form of energy could be substituted for any other form, which is far from being the case. In reality, the limits to the substitution of one form of energy for another are determined by the form of useful energy finally produced. It would not be possible for coal, for instance, to displace the use of oil for road transport purposes. Owing to lack of knowledge concerning the efficiency of conversion of the various forms of energy into useful energy, it is in fact extremely difficult to estimate the net requirements, although their satisfaction is the ultimate object of all activity in the energy economy. These problems, and the means of solving them, are the subject of the remainder of this chapter.

1.7 Determination of a common unit

For the purpose of a comprehensive energy balance sheet, indicating the total available energy and the total energy needs, a common unit ought to be chosen. Also conversion factors should be determined by which all the quantities of energy in different forms which are available and needed can be reduced to terms of that unit.

The choice of the unit itself presents no great problem; one can take any one of the existing units: the British thermal unit (Btu)¹⁾, the therm²⁾, the calorie³⁾, the kilogram calorie (also known as the large calorie) (kcal)⁴⁾, the thermie (th)⁵⁾, the horsepower hour⁶⁾, the kilowatt hour (kwh)⁷⁾, the kilogram metre (kgm)⁸⁾, or the joule (J)⁹⁾. A further possibility is the coal kilogram equivalent, equal to 7000 kilogram calories, which is often used as a base unit for an energy balance sheet because, in the view of some experts, it offers a more

1) A British thermal unit, or Btu, is equivalent to the quantity of heat required to raise the temperature of one pound of water by one degree Fahrenheit.⁷

2) The therm is equivalent to 100,000 Btu.

3) A calorie is equivalent to the quantity of heat required to raise the temperature of one gram of water by one degree centigrade. The calorie is sometimes called the small calorie or gram calorie.

4) The kilogram calorie, or kilocalorie, sometimes called the large calorie, is equal to 1,000 calories.

5) 1 thermie = 1000 kilocalories

6) 1 horsepower hour = 2544 Btu

7) 1 kilowatt hour = 3412 Btu

8) 1 Btu = 107.6 kilogram metres

9) 1 Btu = 1055 joules = 252 calories.

graphic illustration of a quantity of energy.¹³⁷ Another unit sometimes used is the petroleum kilogram equivalent, equal to 10,000 kcal.

The British thermal unit, the thermie and the kilogram calorie are, in principle, units of heat energy. The first is mainly used in Anglo-Saxon countries and the second mainly in France, while in most other countries the kilogram calorie is adopted as the unit of heat.¹³⁷ This divergence of practice has the disadvantage of hampering the comparability of studies carried out in different countries. It is also one of the reasons why it would not be very practical to use the horsepower hour for the establishment of energy balance sheets. The use of this unit is limited; it has almost universally been replaced by the kilowatt hour, which is primarily the unit of electrical energy.

The kilogram metre is used only as a unit of mechanical energy, and is, moreover, not used in Anglo-Saxon countries. It is therefore unsuitable for energy balance sheets. On the other hand, the joule is a unit in the Giorgi system (M-K-S System), which has been adopted internationally. The joule is used by physicists all over the world to express quantities of mechanical, electrical and calorific energy. Accordingly, it is the most appropriate unit for expressing the physical energy content of the various energy-producing agents appearing on an energy balance sheet.

1.8 The stages of the energy economy

The energy balance sheet always compares energy resources broken down according to energy-producing agents, with energy needs broken down according to the various forms of energy taken up by the final consumer. Most often, such surveys are drawn up in balanced form, the excess representing the energy losses occurring in the transmission or transport of the energy and in its various conversion processes. Some energy is consumed in the production of primary energy-producing agents and some in the conversion of energy, and this consumption is not therefore included in the quantities

of energy supplied to the final consumers. That is why, in a more searching analysis of the energy economy, four principal stages of energy are distinguished in the progress of the energy from the natural resource to its end-use. These stages, for each of which an intermediate energy balance sheet can be drawn up, are:

- (i) the stage of the gross energy resources
- (ii) the energy conversion stage
- (iii) the stage of the final consumption of energy, and
- (iv) the stage of the consumption of useful energy.

(i) The intermediate balance sheet relating to total gross energy resources shows the gross energy available (gross production of primary energy, plus primary and secondary energy imports), as compared with the net primary energy available, energy consumed for the production of primary energy, and energy exports. From this balance sheet one can tell, for instance, the efficiency of the production of each of the primary energy-producing agents.

(ii) The balance sheet relating to energy conversions compares the energy inputs to the various conversion processes with the useful secondary energy outputs, the by-products (if any), and the conversion losses. At this stage, a number of commercial conversion processes are usually differentiated, including:

- thermal power stations,
- natural gas liquefaction plants,
- petroleum refineries,
- oil from coal refineries,
- coke ovens, and
- gas works.

Blast furnaces are also often included, because, although they are used for the production of pig iron, they supply blast-furnace gas, which

is in effect an energy-producing agent resulting from the conversion of part of the coke charged. If account is taken of fissile and fertile nuclear materials in assessing the total primary energy available, then account should also be taken of nuclear reactors at the energy conversion stage.

By means of the conversion balance sheet, it is possible to compute the efficiency of each of the commercial conversion processes, and also the overall efficiency of the conversion.

Some experts hold that it is useful to show in an energy balance sheet all the intermediate conversions of the commercial conversion processes which consist of a chain of successive conversions; the coal-steam-mechanical energy - electrical energy series of a thermal power station, for example.¹³⁷ Although such a detailed analysis might be of some importance in research into the causes of losses, it is not of importance for an economic analysis. Moreover, it sometimes happens that, in the absence of statistics concerning these intermediate stages of conversion, the efficiency of certain intermediate conversions has to be estimated, which renders this detailed analysis pointless.

(iii) An intermediate balance sheet relating to the stage of the final consumption of energy should show the amounts of energy available for final consumption, broken down by form, on the one hand, and by a number of sectors characteristic of consumption, on the other.

(iv) The consumption of useful energy is sometimes omitted from an energy balance sheet because of the lack of accurate information - statistical data concerning the quantities of energy usefully consumed for a particular purpose, and, usually, accurate information on the quantities of useful energy consumed. It is impossible, however, to neglect the study of trends in the consumption of useful energy in any accurate study of trends of consumption of energy. Such a study is made by estimating the quantities of the various forms of energy which, within the various

consumption sectors, have been consumed as heat, as mechanical energy, as light, or for other than energy-producing purposes. By adopting average efficiencies for these latter conversions it is possible to form estimates of the consumptions of these three forms of useful energy within the different sectors of consumption, and so to determine their trends.

This analysis can also take the form of an intermediate balance sheet in which the quantities of energy usefully consumed are compared with the quantities of useful energy effectively produced. From this balance sheet the average efficiency of the final consumption of each commercial form of energy can be deduced - a basic figure for the establishment of a comprehensive balance sheet expressed in equivalent quantities of useful energy.

In some energy balance sheets, for example, those drawn up in Belgium, Bulgaria, Italy and Spain, final consumption of energy is not indicated by the form of useful energy produced; nor is the efficiency estimated.¹³⁷ Account is, however, taken of the utilization efficiency of each energy-producing agent separately in a number of consumption sectors. In this way, the consumption of useful energy by each of these sectors can be determined without the need for an analysis according to its different forms. This analysis can also be given in an intermediate balance sheet which indicates, on one hand, the amount of different energy-producing agents usefully consumed by a number of consumption sectors, and, on the other, the useful energy produced on the basis of each of these amounts.

In this way, the efficiency of the final consumption in respect of each consumption sector in question, the average efficiency of the final consumption of each of the energy-producing agents taken into account, and the overall efficiency of the final consumption of energy can be determined.

1.9 Different methods of analysing the energy economy

The available methods which are applied by various countries in the world for analysing their energy economies can mainly be classified into:

- (i) energy balance sheet methods, and
- (ii) other methods.

1.9.1 Energy balance sheet methods

Whatever form an energy balance sheet may take, it should be constructed from a large quantity of statistical data concerning the gross and net resources of the various energy-producing agents and their absorption by the different consumption sectors.

The quantities available for consumption in any one year are derived from the gross quantities produced in the same period, adjusted to allow for amounts consumed for production purposes, variations in stocks, bunkered stocks, imports and exports. Part of these quantities is taken up by the converting industry, another part is lost in transport and distribution, and the remainder, subject to distributor stock fluctuations, is absorbed by the final consumers.

For a detailed analysis of the energy economy it is also necessary that the statistical information should be such as to enable the final consumptions to be broken down by major types of consumer sector.

From all this statistical information a partial balance sheet expressed in the units appropriate to each particular source, (tons, cubic feet, kwh), can be established in respect of each energy-producing agent. From these partial balance sheets a number of surveys of the energy economy can be derived:

- (i) a survey of the gross and net resources of the various forms of energy,
- (ii) for each conversion process, a survey showing the quantities

of the various forms of energy absorbed, and the quantities of energy produced by the process,

- (iii) a survey of imports and exports of the various forms of energy, and
- (iv) a survey of the quantities of the various energy-producing agents taken up by final consumers, with a breakdown by typical consumption sector.

However, although such surveys convey a relatively complete picture of the energy economy, they cannot offer an indication concerning such matters as the relative prominence of the various forms of energy in indigenous energy production, in imports and exports, and in the energy consumptions of the various groups of consumers. Nor do they give any particulars of the efficiency of the production, conversion and utilization of the different forms of energy. Accordingly, they are deficient in the specification which may reflect the state of affairs in the energy economy of a particular country and from which one can tell the trend of the energy economy. Yet, the object of an energy balance sheet is precisely to convey an idea of the energy economy as a whole, so that specific data of this kind can be more easily extracted. Naturally, its form will depend on the desired objective.

In the present section, the various balance sheet methods which have been prepared or suggested with a view to achieving a more thorough analysis of the energy economy will be discussed, and consideration will be given to what extent these various methods are suited to the several purposes of the analysis.

1.9.1.1 The method of physical energy content

A principle often applied for the purposes of expressing the various forms of energy in a single common unit is that of conversion on the basis of the physical energy content. The joule would therefore seem to be the best common unit for an energy balance sheet if the principle of the

physical energy content has been adopted. Thus, quantities of electrical energy appearing in the energy balance sheet, for example, are then converted on the basis of:

$$1 \text{ kwh} = (3.6) 10^6 \text{ joules}$$

Similarly, quantities of solid, liquid or gaseous fuel can be converted on the basis of the gross¹⁾ or net²⁾ calorific value of the fuel in question. In some countries, conversion is done on the basis of the net calorific value, but in other countries, notably those of Anglo-Saxon origin, the gross calorific value is preferred.

If nuclear energy is to be included in the energy balance sheet, then the problem of the calorific value of the nuclear fuel arises. As is known, uranium comprises two isotopes; 0.7 per cent ^{235}U , a fissile substance, and the remainder ^{238}U . The latter isotope is not fissile, but if it is exposed to irradiation, ^{239}Pu , (plutonium), likewise a fissile substance, can be produced from it.¹³⁷ Hence, it is possible to determine a calorific value for natural uranium by taking into account the calorific value of its ^{235}U content and that of the plutonium which can be produced by irradiation, and deducting therefrom the calorific value of the ^{235}U which would be consumed to achieve that irradiation. By analogous reasoning, the calorific value of thorium - a fertile nuclear substance which, when irradiated, produces ^{233}U , a fissile nuclear substance - could be determined.

1) The heat evolved during complete combustion of a unit weight of a substance (also called the 'gross heat of combustion'), usually expressed in Btu per pound weight.¹⁷

2) Gross heat of combustion minus the latent heat of condensation of any water produced, (also called the 'net heat of combustion').¹⁷

By means of these principles it would also be possible to include in the energy balance sheet the energy content of the irradiated fuel removed from nuclear reactors and to follow up, from this point of view, the treatment of irradiated fuels and their re-use in nuclear reactors. However, as the energy balance sheet of nuclear reactors is in any case very complicated, their inclusion in the general energy balance sheet would no doubt complicate it. Some experts prefer, therefore, to leave nuclear fuels outside the energy balance sheet and to take into account only the heat or electrical energy produced by nuclear power stations.¹³⁷

An energy balance sheet established on the basis of the physical energy content of the different energy-producing agents is made up from a number of partial balance sheets, one - as complete as the available statistics allow - for each energy-producing agent of material importance. The quantities shown in this balance sheet, originally expressed in the customary units, are then converted into quantities of energy on the basis of their physical calorific value. The quantities of energy so computed are then used for establishing an intermediate balance sheet for each of the four stages of the energy economy:

- (i) The balance sheet of the total energy available will indicate for each primary energy-producing agent and for each secondary energy-producing agent imported, and for all these energy-producing agents in aggregate, the gross and net energy available, the quantities of energy used for conversion, the quantities available for ultimate consumption, and the quantities exported.

On the basis of the information given in such a balance sheet it is easy to express the relative importance of each form of energy in the total, the relative importance of imports and exports, and the relative importance of the energy used for conversion and for final consumption.

- (ii) The energy conversion balance sheet will indicate, for each of the principal conversion processes, the quantity of each form of energy used for conversion, and the quantity of secondary energy (of each form if the process concerned yields more than one form), produced.

From this, one can work out the ratio between the quantities of the various energy-producing agents consumed in the conversion process and the total energy input or the secondary energy usefully produced. In addition, the total efficiency of each conversion process, and the overall efficiency of all commercial conversion processes taken together, can be worked out.

- (iii) The balance sheet of the final consumption of energy will indicate, firstly, the quantities of the various forms of energy taken up by the final consumers and, secondly, how this is apportioned among certain typical consumption sectors.

In this way, it becomes possible to express the relative importance of each form of energy in the total final consumption of energy and in the total energy consumption of each typical consumption sector.

- (iv) Lastly, the balance sheet of the consumption of useful energy should indicate, in respect of each typical consumption sector and of each form of energy intended for final consumption, the apportionment according to final use and the quantities of useful energy produced. Another method consists in drawing up separate balance sheets for each consumption sector, in which the quantities of different forms of energy consumed are compared with the amount of useful energy into which they were converted during the final consumption - the form of useful energy being disregarded for this purpose. However, the

establishment of such balance sheets is hampered by the lack of sufficiently detailed statistics. To overcome this difficulty, it is general practice to estimate the apportionment according to the final use of the energy consumed on the one hand, and to the efficiency of the final conversion on the other. Tables 1 to 4, prepared by a Secretariat of the Economic Commission for Europe^{13/}, provide data concerning the efficiency of the final conversion adopted in certain countries and by two international organisations.

TABLE 1: EFFICIENCY OF CONVERSION INTO USEFUL ENERGY: LIGHTING

COUNTRY	PURPOSE OF FINAL CONSUMPTION	EFFICIENCY OF CONVERSION INTO LUMINOUS ENERGY IN PER CENT		
		ELECTRICAL ENERGY	PETROLEUM PRODUCTS	GAS
Austria	Lighting			
	- independent skilled trades	6	0.5	
	- domestic	4		
Belgium	Lighting	15 ¹⁾		
East Germany	Lighting	4		1

1) In relation to an ideal source of white light having a luminous efficiency of 185 lm/w.

TABLE 2: EFFICIENCY OF CONVERSION INTO USEFUL ENERGY: TRANSPORT

COUNTRY OR ORGANIZATION	PURPOSE OF FINAL CONSUMPTION	EFFICIENCY OF CONVERSION INTO MECHANICAL ENERGY, IN PER CENT											
		SOLID FUELS				PETROLEUM PRODUCTS			GAS			STEAM	ELECTRICAL ENERGY
		COAL	COKE	LIGNITE	WOOD	FUEL OIL	PETROLEUM ETHER	MOTOR FUELS	NATURAL GAS	LIQUEFIED GAS	MANU-FACTURED GAS		
Austria	Transport	-				25			-			10	80
Bulgaria	Transport	4.1	-	40		28			-			-	80
Italy	Transport (Services)	7	-			23			22	25	-	-	85
OEEC	Transport	5				22-25							85
Belgium	Railway	5 to 6	-				22 to 25		-			-	80
Eastern Germany	ditto	8	-			-	25	25	-			-	80
Western Germany	ditto	5	-			5	20	-	-			-	75
ECSC	ditto	5	-			7	25	-	-			-	85
Spain	ditto	5				7	25	25					85
Eastern Germany	Navigation	5	-			-	-	25	-			-	-
Western Germany	ditto	5	-			5	20	-	-			-	-
ECSC	ditto	5	-			7	25	-	-			-	-
Spain	ditto	5				7	25	-					
Belgium	Air transport	-				20			-			-	-
Eastern Germany	ditto	-				-	-	20	-			-	-
Western Germany	ditto	-				-	-	20	-			-	-
ECSC	ditto	-				-	-	22	-			-	-
Spain	ditto							22					
Belgium	Road transport	-				20 to 28			-			-	-
Eastern Germany	ditto	-				-	25	25	-			-	-
Western Germany	ditto	-				-	20	20	-			-	-
ECSC	ditto	-				-	25	20	-			-	-
Spain	ditto						25	20					

TABLE 3: EFFICIENCY OF CONVERSION INTO USEFUL ENERGY: HOUSEHOLD USES

COUNTRY OR ORGANIZATION	PURPOSE OF FINAL CONSUMPTION	EFFICIENCY OF TRANSFORMATION INTO USEFUL ENERGY, IN PER CENT							ELECTRICAL ENERGY
		SOLID FUELS			LIQUID FUELS	GAS			
		COAL	COKE	WOOD	PETROLEUM ETHER	NATURAL GAS	LIQUEFIED GAS	MANUFACTURED GAS	
Bulgaria	Household uses	42		38	60				50
Italy	ditto	50	65	45	75	70	70	65	80
ECSC	ditto	50		-	65		75		80
OEEC	ditto		41		68		65		85
Spain	ditto		50		65		75		80
Belgium	Cooking		10 to 20				60 to 65		50 to 65
Eastern Germany	ditto	20	-	-	-		65		65
Belgium	Space heating		40 to 55		65		75		100
Eastern Germany	ditto	50		-	-		75		90
Western Germany	ditto	50	50	-	65		75		80

TABLE 4: EFFICIENCY OF CONVERSION INTO USEFUL ENERGY: INDUSTRIAL USES

COUNTRY OR ORGANIZATION	PURPOSE OF CONSUMPTION	EFFICIENCY OF TRANSFORMATION INTO USEFUL ENERGY, IN PER CENT											
		SOLID FUELS				LIQUID FUELS			GAS			STEAM	ELECTRICAL ENERGY
		COAL	COKE	LIGNITE	WOOD	FUEL	PETROLEUM ETHER	MOTOR FUELS	NATURAL GAS	LIQUEFIED GAS	MANU-FACTURED GAS		
Bulgaria	Industry	45	-		40		45			-		65	80
Italy	Extractive industry	-	80	-	50		80			-		-	80
	Manufacturing industry	70	76	60	50		80		80	80	75	-	85-90
OEEC	Industry			45			59			65		-	80
ECSC	ditto		45		-		59			65		-	80
Spain	ditto			45			59			65			80
Belgium	Industry and iron and steel making	45	45		-		45			65		-	80
Western Germany	Iron and steel making	-	50		-		-			-		-	-
ECSC	ditto	-	50		-		-			-		-	-
OEEC	ditto			45			59			65		-	80
Spain	ditto			50						65			80
Western Germany	Steel furnaces		-				-			-		-	70
ECSC	ditto		-				-			-		-	90
Spain	ditto						59						90
Austria	Stat. engines and motors		-				25		22	-	25	10 - 15	75-85
Belgium	Small-scale motive		-				-			-		-	50
Eastern Germany	Stat. engines and motors		-			-	-	25		25		15	80
Western Germany	ditto		-				-			-		-	70
Austria	Heating applications (industry and small-scale skilled trades)		74.7				80		85	-	85	85	90
Eastern Germany	Industrial heating applications	60		-			-			65		80	80
Western Germany	ditto	40	40		-	40	40	-		40		-	70
ECSC	Industrial furnaces	10-40		-			-			-		-	-

From the balance sheets of the consumption of useful energy one can estimate the average efficiency of the conversion into useful energy for each of the energy-producing agents intended for final consumption. In addition, from these balance sheets one can work out the overall efficiency of final conversion of the total energy consumed.

The set of balance sheets for the various stages of the energy economy is usually supplemented by a total energy balance sheet, in which the gross and net energy available, classified according to form of energy, are compared with the consumption of useful energy, classified according to form and consumption sector and the energy losses occurring at the various stages.

An energy balance sheet of this type is usually illustrated by an energy flow diagram in which the four stages of the energy economy are quite distinct. Such a diagram is particularly useful to illustrate the structure of the energy economy and the interdependence of the different forms of energy.

A detailed energy balance sheet drawn up on the basis of the physical energy content of the different forms of energy therefore makes it possible, firstly, to express in energy quantities and in relative terms the various forms of energy representing:

- total energy available,
- energy used for conversion,
- energy produced by conversion processes,
- energy consumed by the various typical consumption sectors,
- useful energy ultimately consumed by the various typical consumption sectors, and
- losses in conversion and transport (transmission).

Secondly, it enables the calculation of the partial and overall efficiency in the:

- production of primary energy,
- commercial conversion of energy,
- final consumption of energy, and
- total consumption of energy.

Evaluation of the method of physical energy content

An energy balance sheet drawn up in accordance with the above principles is a useful means of describing the structure of the energy economy quantitatively. It is the basis for flow diagrams which makes it possible to distinguish clearly between the four stages of the energy economy and to illustrate its structure in all its details.

Reconversion on the basis of the physical energy content has, however, one disadvantage. The quantity of useful energy which can be produced by the conversion of a primary or secondary energy-producing agent depends not only on the agent's physical energy content, but also on its form (coal, gas, electricity), and on the form of the useful energy to be produced (light, heat, mechanical energy). Actually, the technically possible efficiency of the different processes for the conversion of the various primary and secondary forms of energy into these three forms of useful energy varies greatly. Consequently, the total energy content of the primary forms of energy necessary to satisfy the same requirements of useful energy depends on the distribution of the primary energy-producing agents involved.

A balance sheet established on the basis of energy content is, however, well suited to the study of a single and relatively important energy-producing agent, and of the way in which its use is related to that of other energy-producing agents. But although the energy content affords a clear basis for expressing the relative importance of the different forms of energy, so far as "noble" forms of energy (such as hydro-electric energy), are concerned, it ill expresses the absolute importance of those forms of energy, which is characterised rather by

the very high efficiency of their conversion into any form whatever of useful energy.

This latter difficulty does not arise to the same extent in the study of the equilibrium between coal production and the supply of petroleum products, which is sometimes the object of drawing up an energy balance sheet. The energy balance sheet established on the basis of the energy content is therefore, in principle, appropriate to such studies. But as the section of the energy market concerned with the supply of energy for road transport is practically closed to coal, certain other forms of energy balance sheets, affording a clearer distinction between the various sections of the energy market, are better suited to such studies.

The energy content balance sheet also offers some clue to the causes and magnitudes of losses, and makes it possible to express the efficiency of the various conversion processes and the general efficiency of energy consumption. However, the quantity of energy involved in certain losses inevitably ensuing from the conversion of energy into "nobler" forms is no criterion for measuring the efficiency of the use of some other specific energy-producing agent or the efficiency of certain conversion processes.

Although it is impossible to assess the economic efficiency of the processes in question, the information referred to can be used to determine the total efficiency of use of each of the primary energy-producing agents; this being itself a useful basis for determining conversion factors by means of which other forms of energy balance sheets can be drawn up.

A series of balance sheets of this type, drawn up for a number of consecutive years, provides a useful starting point for the establishment of forecasts, applying the method of analysis by consumption sector.

The establishment of a detailed energy balance sheet of this kind is, however, often hampered by the lack of sufficiently detailed statistical information. If the object is merely to define the relative magnitude of

the shares of the various energy-producing agents, and of indigenous energy production, imported energy and exported energy, in total consumption, it is possible to use comprehensive energy balance sheets drawn up on the basis of the physical energy content of the various energy-producing agents constituting the annual gross available resources and annual gross consumptions.

In conclusion, it seems that this type of energy balance sheet is well suited to research into the structure of the energy economy and that a number of balance sheets, covering a series of consecutive years, may form a useful basis for estimates of future energy requirements. On the other hand, this type of balance sheet is less suited to comparative studies concerning the efficiency of use of the various energy-producing agents and of the various conversion processes. Accordingly, this type of balance sheet does not make it possible to discern the favourable and adverse trends of substitution.

1.9.1.2 The method of conversion based on the equivalence of the useful effects of energy

To overcome the difficulties inherent in the method of conversion on the basis of energy content, the principle of conversion on the basis of the equivalence of the useful effects of energy has been introduced.

This is the principle underlying three different methods of conversion:¹⁸⁷

- (i) the conversion of the quantities of all the energy-producing agents into equivalent quantities of a single energy-producing agent - such as coal, petroleum or electrical energy - that could take the place of all the others;
- (ii) the adoption of fictitious calorific values for the several energy-producing agents, subject to allowance for the differences in the efficiency of the conversion process;

- (iii) the adoption of specific indices for the useful energy content of the various energy-producing agents.

According to the first method, for each quantity of a given energy-producing agent an equivalent quantity of the energy-producing agent used as reference, e.g. coal, is determined - the quantity, that is to say, that would be capable of producing the same amount of useful energy in all its forms. But certain difficulties are involved in the use of this method. First of all, for the purpose of expressing the quantity of a single, specific energy-producing agent in terms of the equivalent quantity of the reference agent, account must be taken of several conversion factors which vary materially according to the final use of the energy. Nor, secondly, is it clear what conversion process should be used as the basis for the calculation of each of these equivalence factors. For what is involved is the replacement of the entire structure of the energy economy by another based on a single primary source. There are several possible solutions to this problem, and it is hard to say what criterion should be adopted for the choice of one of them as a basis for computation. Lastly, the efficiency of conversion to be taken into account depends on the stage of technical development reached, and differs from country to country. Thus the equivalence factors are not constant; they tend to develop with time.

By the second method, the energy content of various energy-producing agents is reduced to quantities equivalent to the energy contained in an energy-producing agent used as reference, e.g. coal. In other words, the notional content of the several energy-producing agents is that which yields the same amount of useful energy when the efficiencies of conversion valid for the reference agent are applied. Needless to say, this method presents the same difficulties as the first method. Besides, it suffers from the further drawback of being apt to cause confusion, for it is hardly logical to take account of different calorific values of one and the same energy-producing agent according to the use to which it is put.

The useful energy content method is, in principle, the reverse of the method described in the previous paragraph. Each energy-producing agent is assigned a specific useful energy content corresponding to the energy produced per unit volume or unit weight of the agent in question after all the intermediate conversions. This method patently encounters the same difficulties as the previous methods; in principle, account should be taken, for each energy-producing agent, of several specific indices of useful energy content according to the final use. However, in less detailed studies which use this method, the difficulty first referred to is often avoided by adopting average efficiencies for the conversions as a whole.

There are three forms of comprehensive energy balance sheets in use which apply the principle of converting the quantities of the different energy-producing agents on the basis of the equivalence of the useful effects of their energy content. These three forms of balance sheets differ mainly in layout and method of construction. They are:

- complete substitution by a single source of energy,
- adoption of fictitious specific values for the energy content of the energy-producing agents, and
- adoption of specific values for the useful energy content of the energy-producing agents.

The first type of comprehensive energy balance sheet is expressed in equivalent quantities of coal, petroleum, or some other suitable energy-producing agent. All quantities of energy-producing agents which are available for gross consumption are converted into equivalent quantities of the energy-producing agent used as reference. This conversion is generally carried out on the basis of a number of equivalence factors which should be determined by a more detailed investigation of the use of each of the primary and secondary energy-producing agents.

The second type of comprehensive energy balance sheet is, usually, also expressed in tons of coal or petroleum equivalent. These quantities are, however, computed on the basis of the fictitious energy content of the various energy-producing agents which represent the resources available. This energy content is computed by adopting the fictitious specific values of energy content of the various energy-producing agents which render them equivalent from the point of view of the useful energy they are capable of generating.

The last type of comprehensive energy balance sheet is expressed in a unit of energy, such as the kcal. It expresses, for each energy-producing agent included among those available, its contents of useful energy. This quantity of energy is usually calculated on the basis of the total efficiency of each energy-producing agent's conversion into useful energy, all the intermediate conversions being taken into account.

These three forms of comprehensive energy balance sheets are thus distinguished from one another only by their layout. Before they can be drawn up, exact conversion factors must be determined by a detailed study of the structure of the energy economy. One possible objection to the first two of these three types of comprehensive energy balance sheets is that the total quantities of the energy-producing agent used as reference represent a quantity of primary energy far in excess of the quantities of energy really involved, a circumstance that might lead to confusion and erroneous conclusions. From this point of view, the method of the useful energy content seems preferable, for the total quantities indicated by such a balance sheet correspond to the total quantities of useful energy actually consumed.

Needless to say, only the method of conversion on the basis of the physical energy content is appropriate to the establishment of intermediate balance sheets relating to each of the four stages of energy in the energy economy. Balance sheets established according to the principle of conversion on the basis of the equivalence of useful effects show

directly the relationship between the primary energy available on the one hand and the useful energy ultimately consumed on the other; they cut out the intermediate stages. But the conversion factors should take account of all the peculiarities of these stages.

Balance sheets of the three types discussed above are therefore unsuited to an examination of the structure of the energy economy, to an examination of the energy market and to a study of the cause of losses. It appears that the only purpose they could serve is for the establishment of forecasts of future energy demand. But it should be noted that the conversion factors which have to be adopted for the establishment of such energy balance sheets are in fact dependent on the structure of the energy economy, on the trend of efficiency of commercial conversions and of conversions into useful energy, and on progress in the substitution of certain forms of energy for others. Therefore, for the precise application of conversion on the basis of the equivalence of useful effects, it is necessary to determine the conversion factors on the basis of a detailed energy balance sheet drawn up according to the method of physical energy content - subject to allowance for all the details of the four stages of the economy.

1.9.1.3 The method of imperfect substitution of an energy-producing agent used as reference

The energy content balance sheet described under section 1.9.1.1 provides a useful basis for forecasting energy needs by applying the method of analysis by consumption sector. This analysis involves a great deal of work, however, and can be properly carried out only if detailed statistics of consumption, and its apportionment among the various consumers, are available. For that reason, long term forecasts are often based on the trend of total gross energy consumption, no attempt being made to break down that consumption among the various consumption sectors or to identify its final objective.

However, as the purpose of studies of this kind is often to forecast the part to be played by certain primary forms of energy in covering total demand, they are based on comprehensive balance sheets in which the total gross consumption of energy, its various forms indicated separately, is compared with the production of primary energy and imports and exports of primary energy and secondary energy.

In section 1.9.1.1 it was also pointed out that the comprehensive energy balance sheet based on the physical energy content is less well suited to such a study because of the considerable differences observed in the efficiency of utilization of the various forms of energy. It is mainly the primary forms of energy which are converted directly into "noble" forms (hydro-electric energy and electrical energy produced by geothermal sources), whose relative importance in the covering of energy requirements is likely to be falsified by their physical energy content. To overcome this disadvantage, quantities of electrical energy of hydro-electric and geothermal origin are sometimes replaced by the equivalent quantities of coal which could have produced the same quantity of electricity in existing thermal power stations. In this way an imperfect substitution energy balance sheet is obtained. ^{12/} ^{13/}

This method has been applied in a number of studies concerning future energy requirements. ^{15/} ^{19/} It has the advantage of being relatively simple and of not requiring a great deal of statistical information. It has the drawback of not being very accurate because it does not take account of the differences in the overall efficiency of utilization of the various primary forms of energy. Nevertheless, this type of balance sheet, covering long series of years, seems to constitute a useful basis for forecasts of future energy requirements in cases where hydro-electric and geothermal energy account for only a modest part of the energy economy as a whole, and where the energy economy as a whole undergoes no great structural change.

It should be noted, furthermore, that the advance of technical knowledge and skill tends to lead to a constant improvement in the average efficiency of thermal power stations, a circumstance which makes it necessary to use different conversion factors for hydro-electric and geothermal energy in balance sheets relating to different periods.

Lastly, it is sometimes practice to construct detailed energy balance sheets by using the method of imperfect substitution, only in respect of gross energy available, while the energy available for final consumption is expressed in terms of physical energy content.

1.9.1.4 The method of conversion based on the exergy of energy-producing agents

An energy balance sheet based on the physical energy content has the disadvantage of not reflecting the economic value of some specific form of energy, which makes it impossible to judge the efficiency in use of the various forms of energy and of the various processes of conversion. To overcome this disadvantage to some extent, it has been proposed that the energy content balance sheet should be supplemented by another based on the exergy. The exergy of an energy-producing agent is its technically usable energy potential, a criterion which would, therefore, distinguish more clearly between the amounts of energy contained in various energy-producing agents. This is the maximum energy that can be extracted from an energy-producing agent in an ideal process. This energy potential, which is called "usable energy" and "available energy" by certain authors, will be referred to as "exergy", a term used in German works on the subject, in order to avoid any confusion with useful energy.¹³⁷ Exergy is equal to the mechanical energy which would be produced by a perfect machine, and is defined by the second law of thermodynamics.

An exergy balance sheet is constructed from the same basic statistical data, but each quantity of energy expressed in original units is converted to its equivalent in exergy.¹³⁷ Such a balance sheet can be as detailed as one expressed in terms of energy. It is also possible to draw up intermediate balance sheets for each of the stages of the energy economy, and to illustrate the structure by a flow diagram.

The balance sheet of exergy reveals certain losses not revealed by the energy content balance sheet. The energy yield of a boiler, for example, is often 80 per cent or more. But for such a boiler the exergy of the steam produced may be as low as 40 per cent of that of the fuel burned. On the other hand, the energy yield of the conversion of natural steam (geothermal energy), into electrical energy is scarcely 20 per cent, but the exergy of the electricity produced may be as much as 75 per cent or more of that of the steam by means of which it was generated.

Consequently, the comparison of the energy content balance sheet with the exergy balance sheet would be a better yardstick for measuring the efficiency of the conversion operations and the real magnitude of the losses. In addition, this comparison would show what conversion processes could be made yet more efficient. It should be noted, however, that about 80 per cent of the energy consumed is converted into heat and that the losses of exergy in this conversion often have little or no influence on the economic value of the heat produced. It would seem that, while energy balance sheets of this kind are unquestionably of great value for research into the efficiency of certain conversion processes, they are less useful as a guide to the efficiency of a country's energy economy as a whole.

Although by means of the energy content balance sheet and the exergy balance sheet it is possible to describe fairly what happens from the physical point of view in the energy economy, these data are not sufficient for an economic analysis of the situation.

1.9.1.5 Methods based on the construction of series of partial energy balance sheets, each covering a separate energy market

As has been seen above, the principal problem in establishing energy balance sheets for the whole of the energy available, and required, in a country lies in the inequality of the economic value of the energy content of the various energy-producing agents. An attempt to eliminate this difficulty has been made by replacing the comprehensive energy balance sheet of the various forms of energy by two or more partial balance sheets each covering only comparable energy-producing agents. A number of proposals have been made in this regard by an energy study group of the Economic Commission for Europe:^{13/}

(i) One proposal of this kind was that the energy economy would be analysed by means of two partial energy balance sheets, one for fuels plus geothermal energy, and the other for electric power.

The fuel energy balance sheet is based on the physical energy content of the various energy-producing agents and expressed in calories. It shows the equilibrium between fuel (classified into the different kinds of fuel), and the geothermal heat available, on the one hand, and fuel consumption (subdivided into eleven consumption sectors, including thermal power stations), on the other. The electrical energy produced by the thermal power stations is shown alongside the electrical energy outputs of the geothermal and hydro power stations on the input side of the electrical energy balance sheet. The total electrical energy available, thus established, could be classified according to the same consumption sectors.

It is also possible to supplement these two balance sheets by an energy flow diagram, which makes it possible to illustrate the structure of the energy economy with a clear distinction between the "noble" form of energy (electricity), and the other forms.

(ii) A second proposal embodies the construction of partial energy balance sheets, each covering quantities of energy-producing agents consumed for the same ultimate purpose. According to this method, the following three partial energy balance sheets would be required:

- energy converted into mechanical energy and light,
- energy converted into heat, and
- energy used for purposes other than energy production.

The first two of these partial balance sheets would each represent an energy market within which substitutions could be effected. This system of three partial balance sheets has the disadvantage that, in general, the existing statistics do not enable consumption to be classified according to final use, and that the problem of the common unit again arises. But, if the total efficiency of the various conversions into useful energy is known, it is possible to express the first two balance sheets in equivalent quantities of the most important energy-producing agent, or in terms of the quantity of useful energy contained in the various agents. Such a system of balance sheets would lend itself, in particular, to a study of trends in the substitution of energy-producing agents for others.

(iii) A proposal concerning, in particular, the study of the structure of energy markets combines the previous two proposals. First, from the total of the energy-producing agents available, those quantities are separated which are consumed for purposes other than the production of energy, (such as chemical synthesis). The analysis of trends in consumption for these purposes involves, as a rule, the establishment of separate balance sheets, one for each of the energy-producing agents concerned, because the possibilities of substitution are limited in this field and depend on the chemical properties of the substance in question, rather than on its energy content.

The entire structure of the energy economy of the remaining available resources (which, after one or more conversion, are used for energy production), is then analysed in three partial energy balance sheets, viz:

- an energy balance sheet for fuels used for heating purposes,
- an energy balance sheet for fuels used for the production of mechanical energy, and
- a balance sheet of electrical energy.

These three balance sheets would be drawn up on the basis of the physical energy content of the various energy-producing agents included in them. The common unit for the first two balance sheets would be a calorific unit, such as the kcal, and that for the third the kwh. Each of these three balance sheets would represent a distinct energy market within which it would be possible to substitute certain forms of energy for others. For an even more accurate analysis of these trends, consumption in the heating balance sheet would have to be subdivided into:

- heating proper,
- metallurgical consumption, and
- heating for productive purposes.

Similarly, in the energy balance sheet for fuels used for the production of mechanical energy, consumption would have to be subdivided into:

- consumption by stationary plant, and
- consumption for transport purposes.

Lastly, in the case of the electrical energy balance sheet, the consumption of electrical energy should be subdivided according to the final use:

- lighting,
- stationary motive power,
- traction,

- space heating,
- heating for productive purposes (furnaces), and
- electronic uses (radio, television).

With such a system of balance sheets it would be possible to study, firstly, the trend of fuel substitution in heating and in the production of mechanical energy and, secondly, the trend of the replacement of fuels by electrical energy.

(iv) Lastly, a system of partial balance sheets can also form the basis for forecasts of future demand, if it is possible to draw up these partial balance sheets in such a way that each of them covers only those energy-producing agents whose reciprocal substitution has little effect on the general result.

Four partial balance sheets, the establishment of which has been proposed for this purpose, are mentioned below by way of example:

- a balance sheet of fuels used for heating purposes,
- a balance sheet of fuels used for mechanical energy production in stationary plant,
- a balance sheet of fuels used for transport purposes, and
- a balance sheet of electrical energy.

Each of the first three balance sheets relates to an energy consumption sector in which, except in such cases as that of coal consumption for transport purposes, the total result is affected only slightly by the substitution of one energy-producing agent for others. As regards the balance sheet of electrical energy, it is linked, through the energy produced by thermal power stations, to that of the fuels used for the production of mechanical energy. In addition, it includes, on its input side, hydro-electric energy and, possibly, electrical energy from geothermal sources.

A series of such balance sheets for a number of consecutive years would show, separately, the trends of fuel consumption for heating, for the production of mechanical energy and for transport, and the trend of the production of electrical energy. These trends would result, on the one hand, from the increase in the consumption of useful energy and, on the other, from the substitution of electricity for fuels of various kinds in the final consumption. In this way, the extrapolation of these trends would make it possible to determine fairly accurately the future fuel requirements of these three consumption sectors, and the total requirements of electrical energy.

1.9.1.6 The method of analysing the energy economy
without drawing up a comprehensive energy balance sheet

In previous paragraphs it was shown that the detailed energy balance sheet established according to the principle of conversion on the basis of the physical energy content is a useful method of depicting the extremely complicated structure of the energy economy in quantitative terms. This form of energy balance sheet does not, however, show the difference in economic value of the various forms of energy. Moreover, it suggests that there is an unlimited possibility of reciprocal substitution of the various forms of energy without affecting the total quantity of energy involved.

Comprehensive energy balance sheets established according to the principle of conversion on the basis of the equivalence of the useful effects of the various forms of energy tend to express the economic value of the various resources available in units of energy, with a consequent risk of confusing the quantities of energy really involved.

Lastly, the comprehensive energy balance sheet established according to the principle of so-called "imperfect substitution", which is an intermediate concept, suffers from the same drawbacks as the previous two categories of energy balance sheets, although to a lesser degree.

The reason for these difficulties is manifestly that the quantities of the various energy-producing agents that play a part in the energy economy cannot be converted into terms of a common unit showing the energy value and the economic value simultaneously. It is well known that the economic value of a quantity of energy depends not only on the energy-producing agent concerned, but also on the final use to which the energy is to be put.

Accordingly, efforts have been made to obviate this difficulty by establishing partial energy balance sheets, each relating only to quantities of energy which are used for the same ultimate purpose. But such partial balance sheets, although useful for analysing the energy market, are less suitable for analysing the energy economy as a whole.

This being so, it seems desirable to consider whether a method of analysing the energy economy can be devised which reduces the use of a common unit to the strict minimum. Such a method should, however, make it possible to work out a number of specific indications which characterise conditions in the energy economy of a particular country or region. A method of this kind has been developed by the Economic Commission for Europe,¹³⁷ and has subsequently formed the basis of the evaluation of the energy economies of various European member states. As an attempt will be made in Chapter 3 to establish the energy balances of South Africa, based on the principles of this method, its ramifications will deserve closer scrutiny. Accordingly, in the following paragraphs the method will be dealt with in detail.

The method of analysis contained in this proposal is based on the combination of partial balance sheets of production and consumption for each of the forms of energy entering into the energy economy. The number of such balance sheets depends, therefore, on the number of energy-producing resources of some significance existing in the country or region whose energy situation is to be examined.

In these partial balance sheets, the quantities of each energy-producing agent concerned will be expressed in the unit usually employed for that agent, i.e.:

- the short, long or metric ton for solid fuels,
- the gallon, barrel or ton for liquid fuels,
- the cubic feet or cubic metre for gaseous fuels,
- the kilogram calorie (kcal) for sources of heat, and
- the kilowatt hour (kwh) for electrical energy.

In addition, the gross or net calorific value, according to the prevailing custom, will be indicated for each separate energy-producing agent taken into account in the analysis. By means of this value, one can, if one wishes, calculate the physical energy content of any of the quantities shown in the partial balance sheet; this may be of some advantage if, for instance, the relative importance of a particular energy-producing agent in the total quantity of energy involved is to be expressed in figures. Because of the confusion to which they may give rise, however, such conversions should be restricted to the unavoidable minimum.

Another important question is the indication of the efficiency of production and conversion processes. Instead of expressing, as a percentage, the efficiency of primary energy production, the efficiency of the conversion of primary into secondary energy, and of final consumption of energy, a number of specific indices will be worked out. This will remove the temptation to compare the efficiency of processes which are in fact not comparable, and to draw false conclusions from the comparison. These indices will, however, make it possible to calculate the energy yield as a percentage, if this information is thought to be absolutely necessary.

The method in question consists, in principle, of establishing a detailed survey of the gross and net energy available, on the one hand, and the apportionment by main consumption sectors and final uses, on the other.

If the object is to analyse the development of the energy economy over a period of several years, it is important to consider more closely the development of the processes for producing primary energy and secondary energy. This is done by analysing primary energy production, on the one hand, and commercial conversions of energy, on the other.

For the purpose of research into the trends of energy consumption with a view to forecasting future primary energy requirements by the method of sector-by-sector analysis, it is necessary to know the trends of useful energy consumption and of energy substitutions. This involves an analysis of the consumption of useful energy, even though this analysis is hampered by the incompleteness and uncertainty of data concerning the ultimate purpose of energy consumption and concerning the efficiency of final consumption.

An analysis of the energy economy according to this method would thus involve the following steps:

- (i) analysis of the gross and net energy available,
- (ii) analysis of primary energy production,
- (iii) analysis of commercial conversions of energy,
- (iv) analysis of final consumption of energy, and
- (v) analysis of useful energy consumption.

These five stages in the analysis will be the subject of the succeeding sections of this chapter.

1.9.1.6.1 Analysis of available energy

Table 5 shows a simplified model with the aid of which a complete survey of the available primary and secondary energy can be drawn up. Each form of energy of some importance in the energy economy of the

TABLE 5: AVAILABLE ENERGY

	PRIMARY FORMS OF ENERGY					SECONDARY FORMS OF ENERGY				
	SOLID	LIQUID	GASEOUS	GEOTHERMAL	HYDRO-ELECTRICAL	SOLID	LIQUID	GASEOUS	HEAT	ELECTRICITY
	..	..	..	..	860	..	..	..	-	860
Calorific value ¹⁾	tons	barrels	cub. ft.	..	kwh	tons	barrels	cub. ft.	kcal	kwh
1 Gross production of primary energy										
2 Balance of external trade (±)										
3 Bunkered ²⁾ (-)										
4 Stock variations (producers and importers) (±)										
5 = 1 ± 2 - 3 ± 4 Gross: quantity available										
6 Own consumption for primary energy production										
7 Transport and distribution losses										
8 Absorbed by conversion industry										
9 Gross production of secondary energy										
10 Stock variations (conversion industries and distributors)										
11 = 5 - 6 - 7 - 8 + 9 ± 10 Quantity available for final consumption										

1) Unless otherwise stated, all calorific values referred to hereafter will represent gross calorific values.

2) Not including bunkered stock used for inland transport.

country to be considered should be represented by a separate column in the table. The five columns under the heading "Primary forms of energy" in Table 5 should, therefore, for the purposes of the analysis, be subdivided in such a way as to provide a separate column for each of the primary forms of energy indicated below:

Primary forms of energy

<u>Solid</u>	<u>Liquid</u>	<u>Gaseous</u>	<u>Geothermal</u>	<u>Hydro-electric</u>
Hard coal	Crude	Natural gas	Hot water	Electricity
Lignite	Petroleum		Steam	
Wood			Electricity	

Similarly, for the five columns under the heading "Secondary forms of energy" in Table 5, the following subdivision may be considered:

Secondary forms of energy

<u>Solid</u>	<u>Liquid</u>	<u>Gaseous</u>	<u>Heat</u>	<u>Electricity</u>
Coal agglomerates	Aviation fuel	Coke-oven gas	Hot water	
Lignite agglomerates	Petrol	Town gas	Steam	
Charcoal	Paraffin	Blast furnace gas		
Furnace coke	Diesel	Refinery gas		
Gas coke	Furnace oil	Chemical industry by-product gas		
Petroleum				

At this stage, it needs to be observed that consumption of energy-producing agents for purposes other than energy production constitutes an additional demand on the market for certain specific energy-producing agents. The same is true of the energy-producing agents absorbed in certain chemical

processes, although a part of their energy content may be consumed as chemical energy or as heat. Since the consumption of certain energy-producing agents in chemical processes is governed by their chemical properties rather than their energy content, it would be sound practice to ignore the useful energy consumed as chemical energy in chemical processes. Rather, all consumption of energy-producing agents in chemical reactions (except energy consumed by the plant for heating and to produce mechanical energy), should be treated as consumption for purposes other than energy production, and should be recorded as such in all cases in which the quantities consumed are not determined by the energy content.

Nevertheless, the classification of coke consumed in steel making raises a specific difficulty. In this process, a part of the coke is consumed for heat and gas production, while another part is dissolved in the pig iron produced. This latter part is, therefore, consumed for purposes other than energy production. In some energy balance sheets,¹³⁷ a distinction is drawn, through the adoption of fixed percentages, between the two parts of the coke used in blast furnaces. In theory, this distinction makes it possible to estimate the amount of coke which can be replaced by other energy-producing agents through the use of other steel making methods, such as low-shaft blast furnaces, although the practical value is, to say the least, doubtful. Since blast furnace gas is a secondary energy-producing agent of some importance to the energy economy, the coke consumed in blast furnaces can be regarded as consumption for purposes other than energy production and blast furnace gases as primary energy. This is in accordance with the practice in some countries where the burning of certain waste products, such as sulphite lye and refuse, as well as the heat produced by certain chemical processes, represent a not insignificant source of energy. This energy, which generally takes the form of steam, is produced by substances which play no role in the energy economy and is normally regarded as primary energy

in the analysis of their energy economies.

Alternatively, the entire consumption of coke can be considered as consumption for energy production, taking blast furnaces as the conversion installations and placing the gas produced under the heading of sources of secondary energy. This second alternative is the one usually adopted and is the principle applied in Table 5.

The analysis of primary and secondary forms of energy, as discussed above, also no longer includes nuclear energy, for its inclusion would give rise to the difficulties referred to in section 1.3.1. The easiest way to take account of nuclear energy would be to record among the primary forms of energy the net quantity of electrical energy and heat produced by nuclear installations. Later on, when nuclear energy assumes a significant role, it will become necessary to provide separate columns for uranium and thorium and for the fissile materials produced by irradiation. Nuclear power plants would then have to be considered in the analysis of commercial conversions of energy.

Lastly, the natural gas derived from certain deposits needs to be dried and sometimes desulphurized. In this case, dry natural gas could be indicated under the heading of secondary forms of energy, taking into account, at the same time, the drying and the conversion installations.

As Table 5 shows, it is intended that the gross calorific value should be shown for each energy-producing agent taken into account. In this connection, it should be noted that when the analysis covers a whole country it is difficult to take account separately of the various qualities of one and the same fuel, such as coal. The different qualities, therefore, have to be entered together in the same column. The figures shown in the column in such a case should, accordingly, be computed by adding together quantities that have been rendered equivalent on the basis of the calorific value entered in the column in question.

Table 5, made up in the manner described, shows, for each primary and secondary energy-producing agent, what quantities are available for consumption after allowing for gross production, external trade, stock variations, losses in transport and absorption by the conversion industries. By means of such a survey it is possible to show, for each energy-producing agent, the relative magnitudes of the quantities absorbed by the conversion industries, of the quantities lost, and of the quantities available for final consumption. By analysing a series of these tables, drawn up for a single region and covering a number of consecutive years, it is possible to compute the trends of production, external trade, and absorption by the conversion industries. Lastly, if the calorific value is taken into account, the data incorporated in a table similar to Table 5 provide a basis for expressing the relative impact of the various forms of energy on the total available; these particulars may be of value in comparative studies.

1.9.1.6.2 Analysis of the production of primary energy

The production of primary energy is analysed on the basis of a survey of data of which Table 6 is a simplified model. The comments in the previous section, concerning the number of columns and the determination of the quantities to be entered therein in cases where different quantities of one and the same fuel are to be dealt with in the same column, are also applicable here.

This survey gives full particulars of the own consumption of various processes for producing primary energy. This consumption includes that involved in the operation of conveyor systems within the producing undertaking, of mechanised extraction equipment and of auxiliary equipment, etc. The energy consumed in the exploitation of a source of primary energy is usually derived, for the most part, from

TABLE 6: PRODUCTION OF PRIMARY ENERGY

	PRIMARY FORMS OF ENERGY					SECONDARY FORMS OF ENERGY				
	SOLID	LIQUID	GASEOUS	GEOTHERMAL	HYDRO-ELECTRICAL	SOLID	LIQUID	GASEOUS	HEAT	ELECTRICITY
	..	..	..	..	860	..	..	..	-	860
Unit	tons	barrels	cub. ft.	..	kwh	tons	barrels	cub. ft.	kcal	kwh
1 Gross production of primary energy										
Own consumption for primary energy production										
- Solid fuels:										
(a)										
(b)										
(c)										
- Liquid fuels:										
Crude petroleum										
- Gaseous fuels:										
(a) Natural gas										
(b) Methane										
- Geothermal energy:										
(a) Steam										
(b) Hot water										
(c) Electrical energy										
- Hydro-electrical energy:										
2 Total own consumption for primary energy production										
3 Net production of primary energy ¹⁾										

¹⁾ Net production of primary energy is calculated by deducting, from the gross production of the energy producing agent in question (line 1), the amount consumed in the production process, disregarding consumption for the production of other forms of primary energy.

the product of such exploitation. Sometimes, however, other forms of energy, brought in from outside, are consumed. These quantities of energy are likewise regarded as part of own consumption for primary energy production, but they are ignored for the purpose of determining net production.

It should be observed, however, that in coal mines certain quantities of coal are usually supplied to the mine's employees free of charge. These quantities should not be regarded as part of the mine's own consumption, for they are a part of the quantities available for final consumption.

It may be noted, moreover, that own consumption in the production of primary energy is in effect a final consumption of energy, inasmuch as it represents a conversion into useful energy in some form. It would therefore be legitimate to take account of this own consumption in analysing the final consumption of energy. That, however, would unnecessarily complicate the analysis, since a large part of this energy is produced by the undertaking that consumed it, and therefore its impact on the energy market is negligible. It, therefore, appears admissible to regard own consumption as energy absorbed in the production process, whatever the useful form in which it was finally consumed.

For the purpose of describing the technical and economic level of the exploitation of primary sources it is possible to work out a specific own consumption index for each form of exploitation. These indices, which can be determined on the basis of the data appearing in Table 6, indicate, to some extent, the efficiency of exploitation. They can be entered in a table modelled on Table 7. If allowance is made for the calorific values of the energy-producing agents produced and consumed in the exploitation of a source of primary energy, then it becomes possible, in addition, to determine the average efficiency of exploitation by means of these indices.

TABLE 7: SPECIFIC OWN CONSUMPTION PER UNIT OF THE GROSS QUANTITY OF PRIMARY ENERGY PRODUCED

		PRIMARY FORMS OF ENERGY					SECONDARY FORMS OF ENERGY				
		SOLID	LIQUID	GASEOUS	GEO THERMAL	HYDRO-ELECTRICAL	SOLID	LIQUID	GASEOUS	HEAT	ELECTRICITY
		..	..	..	..	860	..	..	..	-	860
Calorific values		ton	barrel	cubic foot	..	kwh	ton	barrel	cubic foot	kcal	kwh
Primary forms of energy	unit Refer- ence unit										
- Solid fuels:											
(a)	'000 tons										
(b)	'000 tons										
(c)	'000 tons										
- Liquid fuels:											
Crude petroleum	'000 barrels										
- Gaseous fuels:											
(a) Natural gas	'000 cub. ft.										
(b) Methane	'000 cub. ft.										
- Geothermal energy											
(a) Steam	10 ⁶ kcal										
(b) Hot water	10 ⁶ kcal										
(c) Electricity	mwh										
- Hydro-electrical energy	mwh										

1.9.1.6.3 Analysis of commercial conversion of energy

The conversion of primary into secondary forms of energy accounts for a large part of the energy economy, which is still actively developing, the reason being that secondary forms of energy, such as gas, electricity and petroleum products offer advantages in matters of transport, convenience of use and ease of control.

In an analysis of the commercial conversion of energy it is useful first to establish a general survey, in accordance with Table 8, of the quantities of energy absorbed and produced by conversion plants. It should be noted that, although commercial conversion generally consists of the conversion of primary forms of energy into a secondary form of energy, it also absorbs certain secondary forms of energy, as in the case of the electricity consumed by a gas works. In addition, there are certain secondary agents which are again converted into other forms of energy, as in the case of the coke charged into a blast furnace or the furnace oil consumed by an electricity generating station. For this reason, Table 8 includes, under the heading "Energy absorbed for conversion purposes", columns for primary and secondary forms of energy. The comments in section 1.9.1.6.1, regarding the number of columns and equivalent calorific quantities, are also valid for these columns.

The efficiency of operation of conversion plants can be illustrated by their specific own consumption, on the one hand, and their specific output, on the other. The specific own consumption and the specific output can, in principle, be determined, either per unit of the gross quantity of the energy-producing agent converted, or per unit of the net quantity of the energy-producing agent produced.

The former reference unit is a better means of expressing the specific own consumption and the specific output of processes in which

TABLE 8: COMMERCIAL CONVERSION OF ENERGY

	ENERGY ABSORBED FOR CONVERSION PURPOSES ¹⁾							SECONDARY ENERGY PRODUCED					
	PRIMARY FORMS OF ENERGY			SECONDARY FORMS OF ENERGY				PRODUCTS OF CONVERSION	CALORIFIC VALUE	UNIT	GROSS PRODUCTION	PLANTS' OWN CONSUMPTION ²⁾	NET PRODUCTION
	SOLID	LIQUID	GASEOUS	SOLID	LIQUID	GASEOUS	ELECTRICITY						
	Calorific value												
Unit	tons	barrels	cub. ft.	tons	barrels	cub. ft.	kwh						
- Oil from coal plants								Synthetic petroleum crude	..	barrels			
- Charcoal burning plants								Gas	..	cub. ft.			
- Blast furnaces								Wood charcoal	..	tons			
								Blast furnace gas	..	cub. ft.			
- Coke oven plants								Coke	..	tons			
								Coke oven gas	..	cub. ft.			
- Gasworks								Town gas	..	cub. ft.			
								Gas coke	..	tons			
- Petroleum refineries								Refinery gas	..	cub. ft.			
								Liquefied gas	..	barrels			
								Petrol	..	"			
								Aviation fuel	..	"			
								Paraffin	..	"			
								Diesel	..	"			
								Furnace oil	..	"			
- Plants for combined production of electrical energy and heat								Electrical energy	..	kwh			
								Steam	..	tons			
								Hot water	..	cub. ft.			
- Thermal power stations								Electrical energy		kwh			
Total energy absorbed by the conversion industry													

1) All quantities of energy supplied from outside the conversion plant.

2) Only own consumption of conversion plants' products.

a single energy-producing agent is converted into several secondary energy-producing agents. In this way, it is possible to avoid any difficulty in apportioning own consumption among the different products of conversion.

This method is, however, not appropriate (unless specially adapted), to thermal power plants and plants for the combined production of electrical energy and heat, for these installations are capable of burning several kinds of fuel. The same is true, in some cases, of gas works. This difficulty can be overcome by converting all the quantities of fuels burnt in these plants into equivalent quantities of standardised coal (net calorific value: 12600 Btu per pound weight), and expressing the specific own consumption in terms of gross tons of coal and equivalent consumed.

The indices of specific own consumption per ton of the gross quantity converted, as so determined, can be entered in a table modelled on Table 9. In this table a separate column should also be provided for each form of energy of some importance in the conversion process. The own consumption of the conversion plants - excepting, however, the losses inherent in the conversion processes - constitutes in fact a final consumption of energy, because it is a conversion of energy into a useful form necessary for the operation of the conversion plant. The comments in section 1.9.1.6.2 are also applicable to the own consumption of conversion plants, and hence it seems possible to disregard this own consumption in analysing the final consumption of energy.

Table 10 is a model of a survey of indices of specific production per unit of the gross quantity converted. If the conversion plants concerned turn out several different secondary energy-producing agents, it is useful to enter also, in this survey, the average apportionment of production among the several products of conversion. This apportionment should be determined on the basis of the physical energy content of the products, and expressed in per cent.

TABLE 9: SPECIFIC OWN CONSUMPTION OF CONVERSION PLANTS

CONVERSION PLANT	BASE ENERGY PRODUCING AGENT	CALORIFIC VALUE	SPECIFIC OWN CONSUMPTION OF THE GROSS QUANTITY CONVERTED ¹⁾						
			PRIMARY FORMS OF ENERGY			SECONDARY FORMS OF ENERGY			
			SOLID	LIQUID	GASEOUS	SOLID	LIQUID	GASEOUS	ELECTRICITY
			..	..	..	..	..	..	860
			lbs/ton	barrels/'000 barrels	cub. ft./ton	lbs/ton	barrels/'000 barrels	cub. ft./ton	kwh/ton
- Oil from coal plants	Coal	..							
- Charcoal burning plants	Wood	..							
- Coke oven plants	Coal	..							
- Gasworks	Coal equivalent ²⁾	..							
- Blast furnaces	Coke	..							
- Petroleum refineries	Crude petroleum	..							
- Thermal power stations	Coal equivalent ²⁾	..							
- Plants for combined production of electrical energy and heat	Coal equivalent ²⁾	..							

1) Excluding the consumption of the base agent; including the conversion plant's own consumption of its products

2) The mean specific net consumption is expressed per ton equivalent of standardised coal.

TABLE 10: AVERAGE SPECIFIC PRODUCTION OF THE CONVERSION INDUSTRY

CONVERSION PLANT	PRODUCTS OF CONVERSION	CALORIFIC VALUE	UNIT	AVERAGE SPECIFIC NET PRODUCTION OF THE GROSS QUANTITY CONVERTED	AVERAGE APPORTIONMENT OF CONVERSION PRODUCTS IN PER CENT ¹⁾
- Oil from coal plants - Charcoal burning plants - Blast furnaces	Synthetic Crude	..	barrels/ton		
	Gas	..	cub. ft./ton		
	Wood charcoal	..	tons/ton		
	Blast furnace gas	..	cub. ft./ton		
- Coke oven plants	Coke	..	tons/ton		
	Coke oven gas	..	cub. ft./ton		
- Gasworks	Town gas	..	cub. ft./ton		
	Gas coke	..	tons/ton		
- Petroleum refineries	Refinery gas	..	cub. ft./barrel		
	Liquefied gas	..	barrels/barrel		
	Aviation fuel	..	"		
	Petrol	..	"		
	Paraffin	..	"		
	Diesel	..	"		
	Furnace Oil	..	"		
- Plants for combined production of electrical energy and heat	Electrical energy	860	mwh/ton equiv. ²⁾		
	Hot water	..	cub. ft./ton equiv. ²⁾		
	Steam	..	tons/ton equiv. ²⁾		
- Thermal power stations	Electrical energy	860	mwh/ton equiv. ²⁾		

1) This breakdown should be determined on the basis of the physical energy-content of the conversion products.

2) The average specific net production is expressed per ton equivalent of standardised coal.

By means of surveys in accordance with Tables 9 and 10, it is possible to compare the efficiency of the various conversion processes. Furthermore, such surveys, relating to different periods, provide a clear view of the technical development of conversion processes.

1.9.1.6.4 Analysis of final consumption of energy

Table 11 is an example of a table by means of which a survey of energy consumption can be drawn up. It should show, firstly, the quantities available for consumption - the end result, in fact, of the analysis of the available energy (Table 5). The arrangement of the columns for the various forms of energy has been somewhat changed, however, because the distinction between primary and secondary forms of energy is immaterial in an analysis of final consumption. The comments in section 1.9.1.6.1 concerning the number of columns, and the determination of the quantities to be entered in them, are likewise applicable to the tables analysing the final consumption.

The quantities available for final consumption being taken as a starting point, the consumption of energy for energy-producing purposes proper is determined by deducting from the quantity available for final consumption the consumption of energy-producing agents for purposes other than energy production, subject to allowance for variations in the stocks held by final consumers. Consumption for purposes other than energy production includes the energy represented by the quantities of energy-producing agents consumed in chemical processes, to the exclusion, however, of coke consumed in iron and steel making (see section 1.9.1.6.1). Accordingly, the fact that a part of the energy entering into chemical processes might be consumed as chemical energy is disregarded. On the other hand, the consumption of energy by chemical industries for heating, lighting and the generation of mechanical energy is regarded as consumption for energy-producing purposes.

TABLE 11: CONSUMPTION OF ENERGY

		SOLID FUELS		LIQUID FUELS			GASEOUS FUELS		ELECTRICAL ENERGY	HEAT
		COAL	COKE	CRUDE PETROLEUM	"BLACK" PRODUCTS	"WHITE" PRODUCTS	NATURAL GAS	TOWN GAS		
	Calorific value	..	..	..	..	..	..	..	860	..
	Unit	tons	tons	barrels	barrels	barrels	cub. ft.	cub. ft.	kwh	kcal
1	Total available for final consumption									
2	Variation of end consumer stocks									
3	Consumption other than for energy production: - Chemical industry - Building - Agriculture									
4	= 1 ± 2 - 3 Total consumption for energy production									
	- Iron and steel manufacture - Non-ferrous metals - Chemical industry - Other industries									
5	Total industrial consumption									
	- Transport by water - Transport by rail - Transport by road - Transport by air									
6	Total transport consumption									
	- Mining - Agriculture - Household, small industry									
7	Total consumption by other consumers									

Table 11 suggests a subdivision of consumption for purposes other than energy production in the chemical industry, agriculture and the building industry. This subdivision is suggested only by way of an example; it could be widened according to need.

The consumption of energy for energy-producing purposes is analysed by determining its apportionment among

- industrial consumption
- consumption for transport purposes, and
- consumption by other final consumers.

Table 11 suggests a more detailed subdivision for each of these three headings, again, only by way of an example; the subdivision can be expanded or reduced according to need.

Surveys modelled on Table 11 and covering a number of consecutive years can be used for determining the trends of consumption of the different forms of energy in the various consumption sectors. For a more thorough investigation of these trends, however, and more particularly for an enquiry into the scope and limits of the cross substitution of certain forms of energy, it is essential to apportion final consumption among its various final uses. Tables 12 and 13 are models of tables for such an analysis. Apart from the consumption of hot water and steam for heating purposes, Table 12 represents the two principal fuel markets within which some tendency towards substitution may occur. In addition, Table 13 illustrates the electrical energy market. By means of surveys modelled on Tables 12 and 13 and covering a number of consecutive years, it is thus possible to study substitution trends, both trends within the fuels market and trends concerning the replacement of fuels by electrical energy. It is obvious, however, that for the purposes of such a study, the fuel consumption of the conversion industry must be taken into account.

The apportionment of consumption according to final purpose is usually hindered by a dearth of satisfactory statistical data. In the case of

TABLE 12: FINAL CONSUMPTION OF FUELS AND HEAT

	FUELS, STEAM AND HOT WATER USED AS SOURCES OF HEAT				FUELS USED TO PRODUCE MECHANICAL ENERGY		
	SOLID	LIQUID	GASEOUS	STEAM AND HOT WATER	SOLID	LIQUID	GASEOUS
	Calorific value						
Unit	tons	barrels	cub. ft.	kcal	tons	barrels	cub. ft.
- Iron and steel manufacture - Non-ferrous metals - Chemical industry - Other industries 1 Industrial consumption of fuels							
- Transport by water - Transport by rail - Transport by road - Transport by air 2 Consumption of fuels for transport purposes							
- Mining - Agriculture - Household, small industry 3 Consumption of fuels by other consumers							
4 = 1 + 2 + 3 Total consumption of fuels							

TABLE 13: FINAL CONSUMPTION OF ELECTRICAL ENERGY

		CONSUMPTION OF ELECTRICAL ENERGY SUBDIVIDED ACCORDING TO FINAL PURPOSE				TOTAL CONSUMPTION
		ELEC- TROLYSIS	HEATING	MECHANICAL ENERGY	LIGHTING	
	Unit	kwh	kwh	kwh	kwh	kwh
1 Industrial consumption of electricity	- Iron and steel manufacture					
	- Non-ferrous metals					
	- Chemical industry					
	- Other industries					
2 Consumption of electricity for transport purposes						
	- Rail transport					
	- Road transport					
3 Consumption of electricity by other consumers						
	- Mining					
	- Agriculture					
	- Household, small industry					
4 = 1 + 2 + 3	Total consumption of electrical energy					

electrical energy, it is sometimes possible to work out fairly accurate estimates from the quantities sold at special tariffs: heating tariff, power tariff, lighting tariff. In the case of fuels, on the other hand, there is often a complete lack of statistical data concerning the final purpose of their consumption. Nevertheless, it seems possible to make relatively accurate estimates concerning the final purpose of the consumption of fuels. To begin with, it is known that certain consumptions of fuel have only one purpose, as in the case of the household consumption of solid fuels, which is for heating only, and the consumption of petroleum products for transport purposes, which, in practice, is for the production of mechanical energy. Moreover, it seems possible to estimate, for the various sectors of industrial consumption, the apportionment between consumption for heating and consumption for the production of mechanical energy.

1.9.1.6.5 Analysis of the consumption of useful energy

The analysis of the energy economy often stops at final consumption with a breakdown by consumption sectors and end use of consumption. Although such an analysis reveals the consumption trends of the various energy-producing agents, and certain trends in the cross substitution of energy-producing agents, it does not disclose the trends in the consumption of the various forms of useful energy; yet these trends are basic to all development in this field. It is for the purpose of acquiring a knowledge of these last named trends that the study undertaken has to be taken further by a detailed analysis of the consumption of useful energy.

This analysis is hampered, however, by the complete lack of statistical information about the consumption of useful energy, and, consequently, estimates have to be resorted to. As was shown in section 1.9.1.1, such an analysis is sometimes made on the basis of the final consumption of energy, classified according to consumption sectors and

subject to allowance for the estimates concerning the efficiency of the final conversion, in conformity with the data given in Tables 1, 2, 3 and 4. By means of such an analysis it is possible to identify the trends in the consumption of useful energy in the different consumption sectors.

However, as the form of useful energy consumed determines a group of energy-producing agents competing with one another, it is useful to pursue this analysis so as to determine the trends in the consumption of the various forms of useful energy. In view of the diversity of the estimates on which it would be necessary to base this analysis, however, very accurate results are unobtainable. Nevertheless, if different development trends emerge for the different forms of useful energy, this result will itself be of some value for forecasts of future demand and the investigation of trends in the cross substitution of energy-producing agents.

Consequently, in an analysis of the consumption of useful energy, estimates, concerning the apportionment of the final consumption of the various forms of energy among consumption sectors and among final uses (Tables 12 and 13), are taken as a starting point. Next, one has to estimate the efficiency of conversion into various forms of useful energy for each of the forms of energy taken into consideration and for each of the various consumption sectors. Table 14 is a suitable model for showing these particulars. Lastly, the useful energy consumed can be calculated on the basis of the quantities consumed by the various consumption sectors and for the various purposes, subject to allowance for the corresponding efficiency of conversion.

The result of this calculation is expressed in a common unit of energy and can be entered in a table similar to Table 15. This latter table suggests the choice of the megajoule as the common unit, but in theory any other unit of energy, such as the kilogram calorie or the kilowatt hour, could be used for this purpose. However, as the kcal

TABLE 14: EFFICIENCY, IN PER CENT, OF CONVERSION INTO USEFUL ENERGY

	FUELS USED AS SOURCE OF HEAT			STEAM AND HOT WATER	FUELS USED TO PRODUCE MECHANICAL ENERGY			FINAL PURPOSE OF ELECTRICAL ENERGY CONSUMPTION			
	SOLID	LIQUID	GASEOUS		SOLID	LIQUID	GASEOUS	ELECTROLYSIS	HEATING	MECHANICAL ENERGY	LIGHTING
Calorific value	..	..	..	..	..	..	..	860	860	860	860
- Iron and steel manufacture - Non-ferrous metals - Chemical industry - Other industries - Transport by water - Transport by rail - Transport by road - Transport by air - Mining - Agriculture - Household, small industry											

TABLE 15: CONSUMPTION OF USEFUL ENERGY IN MJ (MEGAJOULES)

	FINAL PURPOSE OF CONSUMPTION			
	ELECTROLYSIS	HEATING	MECHANICAL ENERGY	LIGHTING
- Iron and steel manufacture - Non-ferrous metals - Chemical industry - Other industries 1 Industrial consumption of useful energy				
- Transport by water - Transport by rail - Transport by road - Transport by air 2 Consumption of useful energy for transport purposes				
- Mining - Agriculture - Household, small industry 3 Consumption of useful energy by other consumers				
4 = 1 + 2 + 3 Total consumption of useful energy				

and the kwh are the characteristic units for the measurement of heat energy and electrical energy respectively, the megajoule is better suited to the present purpose, since it is not characteristic of any particular form of energy. As is known, the equivalent values of the megajoule in other units are as follows:

$$1 \text{ MJ} = 0.278 \text{ kwh} = 239 \text{ kcal} = 10^{13} \text{ ergs.}$$

As has been pointed out earlier, the analysis of the consumption of useful energy can only yield results that are relatively imprecise; for in such an analysis two groups of estimates are involved, the first concerning the final purpose of the various consumptions and the other the efficiency of conversion into useful energy. It would seem, therefore, that this analysis could be useful only if it were carried out over a number of consecutive years, in which case it makes it possible to study the development trends in the consumption of useful energy in various forms.

Evaluation of the method

The previous sections have been concerned with the description of a method by which the energy economy can be analysed in all its details, without the establishment of an overall balance in which all the quantities of energy are expressed in terms of a single common unit.

By this method of analysis, however, it is possible to work out characteristic indices for the energy economy, and its development trends, without falling into the errors and confusions which are apt to result from the conversion of the original quantities of the various forms of energy on the basis of a common unit.

Conversion on the basis of a common unit has been found to be essential only in special cases:

- at the energy conversion stage to express the efficiency of electric power stations, of plants for the combined production

of electrical energy and heat, and, in some cases, of gas works;

- at the utilisation stage to express the useful energy consumed.

In evaluating the method in the report in which it was originally published,^{13/} the authors come to the conclusion that the establishment of a comprehensive energy balance sheet is not indispensable to a detailed study of the energy economy. While the description of the method above amply demonstrates this view, it seems as if the usefulness of the method for forecasting purposes has not been fully recognised. For Table 15, in fact, comprises a comprehensive analysis of useful energy consumption, by form, of all energy-producing agents combined. Furthermore, all the forms of useful energy consumption are expressed in one and the same unit, namely the joule, so that there can be no legitimate objection against establishing a total of all useful energy consumed.

This being so, it will also be possible to present an analysis where the contribution of useful energy by each individual energy-producing agent is identified separately, and for each individual consumption sector. If information of this nature is available for a sufficient number of years, it will substantially aid the task of forecasting future demand. The latter approach has been applied with great success by Middelhoek^{20/} in the case of Holland, for instance.

Another limitation of the method discussed by the authors is that concerning the efficiency of final conversion into useful energy. The point is made that, as the efficiency of conversion into useful energy is being steadily improved, it will not be correct, strictly speaking, to apply fixed percentages of conversion into useful energy over a fairly long period of time. But even this problem, it seems, is not insurmountable. For Middelhoek indicates how it is possible to separate, in the analysis,

the influence of substitution on the demand for energy, on the one hand, from the influence of a steadily increasing efficiency of consumption, on the other, if representative percentages of conversion into useful energy are used, over the entire length of the period under study.

The method described above and developed by the Economic Commission for Europe therefore appears to be a very valuable tool for analysing the energy economy, and especially for forecasting future demand. In Chapter 3 it will be indicated that the method is ideal for adaption to the South African environment and, in Chapter 5, a forecast of future demand for energy in South Africa will be attempted on the basis of these principles.

1.9.2 Other methods

It has been indicated that although energy balance sheet methods are of great value in describing developments in the energy economy from the physical point of view, it does not allow for a satisfactory treatment of the equally important economic aspects of the situation. This is so, because, in addition to the energy content of various energy-producing agents, factors, such as relative prices, capital cost of fuel-saving appliances, convenience, controllability, cleanliness and many other economic considerations, determine the equivalence between different fuels.

A number of students in this field have, therefore, attempted to devise methods which, in addition to the energy content of energy-producing agents, also seek to incorporate their respective monetary values in the analysis. But, although most of these methods have not yet succeeded in solving the basic problems satisfactorily, they deserve mentioning as it tends to lead to better understanding of the problems inherent in the analysis of the energy economy. At the same time, it facilitates a better evaluation of available energy balance sheet methods.

1.9.2.1 A method of analysis based on marginal cost of production
and consumption

This method of analysis, suggested by Turvey and Nobay²¹⁷, concerns itself mainly with the problem of measuring energy consumption, i.e. that of expressing the contributions of the various energy-producing agents by a common denominator. It states that the relevant conversion factors for different energy-producing agents are either their marginal rates of transformation in production, or their marginal rates of substitution in consumption, in the economic sense. Thus, when they are looked at in relation to other production, fuel outputs should be valued at marginal production cost, while, when they are looked at in relation to other purchases, fuel inputs should be valued at marginal cost to the consumer.

If resource allocation is not efficient, however, the approach may not yield a unique answer. In principle therefore, one would like to use both producers' marginal cost weights and weights reflecting marginal cost to consumers. Neither is possible, however, because of the lack of data concerning the marginal cost of producing and distributing the various fuels. Nor is a weighted average available of follow-on rates for gas sold on multi-part tariffs nor for oil nor coal, where quantity rebates are common. Consequently, in order to secure comparability, one has to make do with average revenue per unit sold, recognising that this is only an approximation to the ideal.

The method is therefore based on averages, which are abstractions, and is hampered by a complete lack of the data on which its success depends. Furthermore, it suffers from the same drawback as methods which are based on energy content only, in that it attempts to prove that prices are the only (important) criterion. Lastly, no attempt has yet been made to illustrate how the method could be used to solve the problems associated with the various stages of the energy economy.

1.9.2.2 Methods based on the combination of the energy content
and the monetary values of energy-producing agents

Some students have proposed that the energy content balance sheet and the exergy balance sheet should be supplemented by one in which the quantities of energy are expressed in terms of their monetary value. One method¹³⁷ applied for the establishment of such a balance sheet consists of comparing all the receipts of energy suppliers, classified according to the final use of their products, with their expenditures, subdivided into management expenses, taxes, depreciation, interest and dividend payments, transport and distribution expenses and operating expenses proper. From a study of this kind one can construct a diagram of money-flow showing the final consumers' outlays on light, power, heat and other forms of energy and how these outlays are apportioned among the various commercial forms of energy.

At the next stage, this diagram can show how these different outlays constitute the receipts of the various energy-producing industries, and how the expenses of these industries are apportioned.

Another method, used in Austria and the O.E.E.C. countries as a whole¹³⁷ to establish an energy balance sheet in terms of value, is based on the input - output analysis of the energy-producing industries and the energy transmission services. Thus the "value" of the energy produced is equal to the sum of the expenditures on the purchase of raw materials and all other operating expenses, the latter being regarded as "value added".

It is also possible to represent the value of the energy, so computed, in a flow diagram and to indicate therein how the outlays of typical consumption sectors, in covering their energy requirements, are distributed among the major energy resources.

From a comparison of the energy content balance sheet with the energy value balance sheet one can calculate the average prices of the various forms of energy at each stage of the energy economy. In this way, one

can recognise any distortion of the price structure that might encourage an unfavourable trend in the energy economy as a whole.

The method of describing the energy economy by three structural balance sheets, the first setting forth the energy content, the second the exergy, and the third the value of the energy in the several stages of the energy economy, is not yet widely applied. The energy balance sheet for Austria for the year 1956¹³⁷ seems to be the first attempt to establish a series of detailed balance sheets of this kind.

While it is possible, by using these three balance sheets jointly, to illustrate the structure of the energy market resulting from the interaction of technical and economic factors, the weakness of the method lies in the lack of the data which are required for its application. It does seem as if the method could be applied usefully in centrally planned economies, where the required data could be called for in a less painful way. In the free capitalist society, however, where private enterprise is responsible for significant contributions to energy industries, it would be a more severe problem to obtain the relevant data in the detail required.

1.10 Summary and conclusions

As has been seen in the earlier passages of this chapter, the various methods available for analysing the energy economy are still largely in the evolutionary stage. This is so, partly because of the complexity of the nature of the problem, and partly because of the fact that conditions in the world in general, and in Europe in particular, have only relatively recently necessitated a critical evaluation of the methodology of analysing the energy economy.

In this respect, Europe has led the world, for a number of reasons. Firstly, the post-war economic recovery in Western Europe had the effect of substantially increasing the energy requirements of the region, with

consequent sharply rising imports and balance of payments difficulties. In addition, the only local resource of some significance, namely coal, was facing steady price increases due mainly to unfavourable geological conditions and a structural change of demand. Lastly, events, such as the Suez crises in 1956, demonstrated the vulnerability of Europe concerning such vital matters as energy supply, and the need to increase security of supply has, consequently, given further impetus to the closer study of the problem.

In recent times, therefore, a steady flow of valuable contributions have come from such organisations as the Economic Commission for Europe¹³⁷, the various World Power Conferences and research organisations in various individual countries.²⁰⁷

As has been seen, the individual application of any of the methods of analysing the energy economy is largely dictated by conditions characteristic of a particular country and by the nature of the problem at hand. In South Africa, where coal is a single relatively important energy source, such methods as:

- the physical energy content method,
- the method of equivalence of useful effects, and
- the imperfect substitution method,

could be applied with success.

Of these methods, the method based on the equivalence of the useful effects of energy appears to be the more accurate approach to the problem. Furthermore, as the particular emphasis of this study is on the forecasting of future energy demand in South Africa, preference will be given to the method whereby final consumption of the various energy-producing agents is expressed in useful energy equivalent.

CHAPTER 2

THE ENERGY AND ALLIED INDUSTRIES OF SOUTH AFRICA

2.1 Introduction

The decisive role played by energy in any national economy is constantly illustrated by examples in the world where phenomenal economic growth, or stagnation, has been the result of abundant supplies of energy, or the lack of it. This is why there is a direct relationship between economic growth and the demand for energy in most developed countries of the world. The higher the demand for energy, the larger is the productive capacity of a country. South Africa ranks fourteenth in the world in gross consumption of energy.¹⁹⁷

Coal has hitherto provided by far the preponderant part of total energy consumed and has been almost the sole primary source of industrial and domestic heating. This has been due to the vastness and accessibility of local coal resources. These not only number among the largest and cheapest in the world, but are situated on the outskirts of the Rand mining and industrial complex and within reasonable haulage distance of the Free State goldfields and Durban industrial area.

South Africa is, however, basically a two fuel economy. Oil's share has grown from negligible proportions to 16.6 per cent of the total in 1965¹⁹⁷, while coal's share dropped to 83 per cent, in the same year, from almost 99 per cent in 1910. The rapid increase in the demand for oil in recent years has almost entirely been the result of the growing needs of the internal combustion engine for road transport purposes.

The seventies looming ahead hold the promise of exciting possibilities. The two primary sources, on which the energy economy is currently based, will soon be augmented by two, and possibly three, additional sources of primary energy. In the near future, hydro-electric power will become available from the Orange River scheme. Secondly, plans are being mooted for South Africa's first nuclear power station at Melkbosstrand, near Cape Town. Lastly, the most dramatic recent development has been the discovery of natural gas off the coast near Plettenberg Bay.

Basically, any attempt to preview energy activity must start by looking at supply and demand. In the broad context of energy supply, considerations, such as the adequacy or otherwise of the coal reserves, the political and other implications surrounding dependence on foreign sources of oil, the increasing competition of nuclear electricity, and sufficiency of water supplies, need to be evaluated.

These problems and their solution will be the subject of the remainder of this study. But a study of this nature first requires a more fundamental understanding of the operation of the energy industries. The remainder of this Chapter will therefore deal in greater detail with the coal, electricity and oil industries.

2.2 The coal industry in South Africa

2.2.1 Introduction

Formed 250 million years ago in the Carboniferous Age, the coal resources of South Africa are part of a group of coal-bearing areas spread aeons ago across the world from the southern part of South America to Southern Africa, to India, Malaysia and Australasia.²²⁷

In South Africa, coal measures range from Natal through the eastern, central, northern and western Transvaal into the Orange Free State and the Cape Province. There is coal under vast areas of South African soil.

Today, coal is mined in three of the four Provinces of the Republic and the winning of coal has developed over the years into a vigorous industry. It has grown side by side with the gold and other mineral industries. Abundant supplies have indeed made easier the growth of South Africa's vast mining industry and the secondary industries which followed in its wake. Coal helped the rapid development of the country's rail transport system, and may well be said to have powered the revolution which changed the country from a comparatively poor pastoral territory into the most advanced industrial state on the African Continent.

There is ample evidence that coal was mined in South Africa - on a small scale - in pre-European times. In Zululand, for example, archaeologists have unearthed old slag heaps containing coal, and there is little doubt that primitive weapons and agricultural implements were smelted, and later forged, in fires made with this fuel.²³⁷

Europeans in South Africa first mined coal in the Cape Province. Today, the Transvaal is the most important producer, followed by the Orange Free State and Natal. At present, no coal is being mined in the Cape and no economically worth-while deposits have been found in South West Africa.

The first actual discovery of coal in South Africa by Europeans is recorded to have taken place in the French Hoek Valley near Stellenbosch about the year 1699.

In 1852, a prize of £100 (R200) was offered for the discovery of coal "sufficiently near Cape Town to be cheaper than importing it."^{23/} It is recorded that very thin deposits of coal and coal shale were at the time discovered in the Cape Flats, but they were commercially of no value. Some years later, the mineral was found and mined at Indwe in the North-Eastern Cape. Almost all of it went to the Kimberley diamond fields.

British Settlers discovered coal in 1838 in Natal.

In the Breyten area of the Eastern Transvaal, collieries of the simplest type came into production on a very small scale during the second half of the nineteenth century. Thomas Baines recognized coal in the Witbank area while trekking from the Transvaal to Natal some two decades later, and mentioned that the quantity in the area was practically unlimited. In later years he was proved correct and the Witbank - Middelburg - Ermelo area is responsible today for more than 60 per cent of the whole of South Africa's coal output.^{22/}

George William Stow, a self-taught geologist, discovered coal in the Orange Free State in 1872 - then the Orange River Colony. It was his intention to take coal from the Vereeniging area to the Kimberley diamond mines by boat down the Vaal River, but, after surveying the river, his idea was abandoned.

In 1887, coal was discovered only twelve miles east of Johannesburg, at Boksburg. Three years later, coal was delivered to Reef gold mines from this area by the so-called "Rand Tram" - a local railway. Soon afterwards, the mineral was also discovered at Brakpan, and then at Springs. But soon the pounding of the gold mills could be heard in these new coal mining areas and coal was doomed to make way for gold

on the East Rand.

Over the years, scientific methods of mining coal have been introduced. The coal industry has followed modern trends and has succeeded in increasing productivity, largely through mechanization. In recent years, many mines have further installed coal washing plants to upgrade the quality of their product.

Main users of South Africa's coal are power stations which generate the world's cheapest thermal electricity at the pithead.²²⁷ Industry is the second largest consumer, followed by the South African Railways. The balance goes to South Africa's mines, to coke manufacturers, to domestic users, for bunkers and for exports.

In the early days of the industry's history, keen competition and dwindling profits forced producers to co-operate if the industry was to operate on a viable basis and the needs of the country were to be met adequately. The producers had to get together to arrange the orderly distribution of sales, in all sizes and qualities. This they did, giving rise to the formation of selling organisations, now known as The Transvaal Coal Owners Association, The Natal Associated Collieries and The Anthracite Producers Association, and Coke Producers (Pty) Limited.²⁴⁷

Although coal is facing increasing competition from oil, hydro-electric power and nuclear fuels, it is expected to remain, for many years, the chief primary source of energy for the country's generation of heat, light and power. South Africa is the largest coal producing country in the Southern Hemisphere today.²²⁷

2.2.2 Classification standards for coal

From the earliest days of trade in coal, certain names have been in use to distinguish different varieties, such as lignite, bituminous and anthracite. These names, or their local equivalents, have been in common use almost throughout the world and, as a general broad classification, they served their purpose reasonably well. However, with the growth of a specialised fuel technology and the development of heating units designed to burn specific grades of fuel, it became necessary to adopt some more definite means of classifying coal according to its composition and heat value.

Lignite is the lowest ranking coal. It is brown in colour, has a moisture content up to 40 per cent by weight, and disintegrates on exposure to air. Lignite has only about half the heat value, weight for weight, of a good bituminous coal and is, therefore, more expensive to transport in terms of heat value per ton.^{25/} Lignite occurs in the Knysna and Vanrhynsdorp districts, but no exploitable deposit has yet been located.^{26/}

Bituminous coals have been divided into two main classes, of which the lower grades, with properties lying between those of lignite and the more volatile bituminous coals, are classified as sub-bituminous (or black lignite). While the heat value of lignite ranges around 6250 Btu per pound weight, for sub-bituminous coal it lies between 7500 and 11000, and for good bituminous coal between 11000 and 13500 Btu per pound.^{25/}

Good quality bituminous coal can be stored away for many months with little or no alteration to its composition. For this reason, bituminous coal is widely used for industrial and household purposes.

This type of coal constitutes about 52 per cent of the current world supply, and certain grades are eminently suitable for the manufacture of metallurgical and blast furnace coke.²⁵⁷

Anthracite coals are hard, dense, low in moisture and high in carbon content. As a fuel, anthracite burns with very little smoke and is therefore very popular for domestic heating purposes. Heat values range from 11500 Btu per pound for meta-anthracite to 13000 Btu per pound for semi-anthracite.²⁵⁷

It would appear that there is no general classification standard for South African coals.²⁵⁷ Export and bunker coals are, however, subject to grading regulations prescribed by the Fuel Research Board and administered by the Fuel Research Institute. The history of these regulations dates from the years immediately after the First World War, when export and bunker coals were in very great demand. More attention was paid to quantity than to quality, and serious injury was done to the reputation of South African coal. A Commission was appointed in 1920 to investigate these matters and, as a result, a Coal Grading Act was passed by Parliament in 1922, and a Fuel Research Board and Fuel Research Institute were established in 1930.²⁵⁷ The grading of coal is today carried out by the Fuel Research Institute, and grading certificates are compulsory in respect of export and bunker coals. Although provision is made in the regulations for the grading of inland coal, it is not compulsory and it appears as if this stipulation is not stringently enforced.

Throughout the collieries of the Republic marketable coal is classified as follows:²⁷⁷

Rounds	:	+ 1 $\frac{1}{4}$ " or where cobbles are extracted + 3 $\frac{1}{2}$ "
Cobbles	:	+ 1 $\frac{1}{4}$ " - 1 $\frac{1}{2}$ " - 3 $\frac{1}{2}$ "
Nuts	:	+ $\frac{3}{4}$ " - 1 $\frac{1}{4}$ " - 1 $\frac{1}{2}$ "
Peas	:	+ $\frac{3}{8}$ " - $\frac{3}{4}$ "
Duff	:	- $\frac{3}{8}$ "

These sizes refer to the diameter of round holes.

Export and bunker coal usually calls for maximum sizes, while large thermal power stations prefer nuts and peas. Cobbles are consumed largely in S.A.R. locomotives, industrial boilers of medium sizes and household appliances. Duff is burned in some large power stations (after pulverising), and is used for the manufacture of coke.^{27/}

2.2.3 Coal reserves

It is difficult to perceive any other subject, of more integral importance to the energy economy of South Africa, which has generated more controversy, delusion and erroneous judgment, than the coal reserves of the country. The premise of coal for a thousand and more years has long been the happy and confident assumption on which arguments regarding future energy supplies of the country were based. By way of illustration, the following is an indication of a number of predictions expressed, since 1913, on the adequacy of the Republic's coal reserves:

<u>Source</u>	<u>Year</u>	<u>Reserves in millions of short tons</u>
1. Twelfth International Geological Congress (Canada). ^{28/}	1913	in situ: 74,900
2. W.J. Wybergh. ^{29/}	1928	225,000
3. F.A. Venter. ^{30/}	1950	74,872

<u>Source</u>	<u>Year</u>	<u>Reserves in millions of short tons</u>
4. Report of the Commission of Enquiry into the application of nuclear power in South Africa. ^{31/}	1961	in situ : 40,000 potential : 80,000
5. Atomic Energy Board. Mikroekonomiese beskouings ten opsigte van siviele kernenergie. PEL CV 10., by J.J.Human. ^{14/}	1967	in situ : 79,867
6. Report on the investigation into the possible introduction of nuclear power in the Republic of South Africa. ^{32/}	1968	in situ : 36,600 mineable : 14,000 saleable : 11,500
7. Report of the Coal Advisory Board. ^{33/}	1970	Mineable: - in situ : 26,504 - extractable 12,619 - saleable : 11,558 Potential: - in situ : 37,351 - extractable 20,813 - saleable : 18,112

The latest estimate of the Department of Planning,^{33/} based on information from coal mining companies, has severely jolted optimism, and available information suggests that the Republic's coal resources are not sufficient to satisfy anticipated demand for the next century.

According to the report, many previous estimates of coal reserves, several of which have been highly optimistic, were based on three erroneous assumptions. First, in situ reserves of coal are not as extensive as was commonly believed; secondly, they did not consider that a relatively large proportion of the coal would be left underground

and, thirdly, it was not appreciated that the demand for coal was growing at about 4 per cent per annum. The last observation will be examined in closer detail in Chapter 5 of this study.

Referring to the problems of determining South Africa's coal reserves, the report states that one of the main reasons for the general air of optimism regarding coal reserves is the fact that previously published reports on "coal reserves" and "proved coal reserves" were taken at their face value, whereas in most cases the precise meaning of these terms was not defined. It is, therefore, necessary to consider exactly what is meant by these terms.

In this regard, it is first of all necessary to distinguish between reserves - which are economically exploitable deposits of which the magnitudes are known within definite limits - and resources, which simply denote known occurrences of coal, where the magnitude of the deposit and the economic exploitability are neither known, or are such that exploitation is not warranted at present.

In estimating the value of coal deposits, the terms "proved reserves", "probable reserves" and "possible reserves" have often been used rather loosely. In an exploration programme, the degree of certainty with which the magnitude of coal deposits in a given area is known is a function of the spacing of exploration holes, the variability of the seams with regard to thickness and quality, and the amount of faulting, dolerite intrusions present, and so forth. Even today, the spacing of exploration boreholes, particularly in the explored but unmined areas, varies greatly and so consequently does the degree of certainty with which the reserves are known.³³⁷

In determining the in situ reserves and resources of South Africa's

coal, one is faced with various problems. These can be briefly summarized as follows:-

- (1) Inadequate information. It has been pointed out above that the more information from actual mining, exploration drill-holes, geological and geophysical mapping, chemical analyses, and other physical and chemical data that are available, the more accurately the amount of coal in situ can be determined. In many of the Republic's coalfields there is not enough information available to calculate the in situ "reserves" with the desired degree of accuracy.
- (2) Physical variability of coal seams. The effects of folding, faulting, washouts, denudation, dolerite sills, and variation in the thickness and number of seams have to be quantitatively known before an accurate calculation of the reserves of coal in a given area can be made.
- (3) Quality of coal. Coal seams in South Africa are generally variable in quality vertically throughout the seam and laterally over the coalfield - frequently even extensively within the confines of a farm or a mining lease. In areas where two or more seams are present the quality and characteristics of the coal may vary appreciably from one seam to another. It is also characteristic of South African coal that a fair to high proportion of the associated mineral matter is so intimately disseminated in the organic matter that it is virtually inseparable. The coal in the vicinity of dolerite dykes and sills is usually altered to such an extent that it is no longer worth considering in the calculation of reserves.

The report shows that the presence of faults, washouts and dolerite sills have had a very marked effect on the Republic's coal resources.

Over and above all these factors, an adequate knowledge of the pre-coal paleogeography is an important consideration in the more accurate determination of the extent of some of the coal deposits. The geological departments of the major coal-mining companies are well aware of this and are doing valuable research in this regard, but the Geological Survey could undoubtedly make a bigger contribution in this respect, if staff were available.³³⁷

It was suggested that extractable reserves should be given as (a) technically extractable reserves, and (b) economically extractable reserves. After careful consideration, it was decided that this could not be done for the following reasons:

- (1) In some of the coalfields, where little or no mining has taken place, it is not yet known what proportion of the seams could be mined, or what mining methods would be used. This applies particularly to the deeper parts of the Waterberg field. More information is required about the physical properties of the rocks, the thickness of coal seams, the distances between seams, roof and floor conditions.
- (2) In some cases, 100 per cent of the coal could be recovered by, for instance, open pit mining, but the cost would be prohibitive. Insufficient information is available to determine how much coal could be extracted at various price levels.
- (3) Policy and demand factors also have an influence on the proportion of coal that can be mined.

It has been pointed out that most of the previous estimates of the Republic's coal reserves were based on in situ reserves. It is, however, a well known fact that not all the coal in situ can be extracted. On a world-wide basis, it is generally considered that roughly about 50

per cent of the coal in situ can be regarded as extractable. It is, however, true that conditions vary so much from one locality to another that each coal property must be analysed as a separate entity to arrive at the most likely extractable reserves.

In considering the extractable proportion of in situ reserves, the following aspects are of importance:

- (1) Maximum mining height. The mining methods and economics have an influence on the maximum mining height.
- (2) Size of pillars and bords.¹⁾ The size of pillars and bords are dependent on the depth of burial, the height of the workings, and on the strength of the coal. Considerable research has been done in this respect and is still in progress.

1) Coal is usually mined by the "bord and pillar" method inherited from Europe. "Bord" is an old English word meaning "house", and a Yorkshire miner, digging himself a "bord" in a coal seam, also spoke of the "roof", the "floor" and the "walls" of the cell he excavated.

When a "bord" was hollowed out to about three square yards, the olden-day miner moved on and began another. The coal left standing between the "bords" was named a "pillar".

South Africa's mines generally practise a modern version of "bord and pillar". Parallel roadways are driven from the shaft and are connected by "bords" of up to 20 feet in width.³⁴⁷ Although this method of exploitation generally leads to lower extraction costs, it is wasteful of reserves, as a large percentage of the mineable coal is left underground as supports in pillars. In some cases, it results in more coal being left underground than was removed.³⁵⁷

- (3) The effects of bad ground. Faulting, washouts, and dolerite intrusions have already been mentioned under in situ reserves. Apart from the devolatilization of coal, there may be deleterious effects on the strength of the coal and associated rocks as a result of dolerite intrusion, so that coal of a saleable quality cannot be economically mined.
- (4) Mining of closely spaced seams. If two seams of say 15 feet each are separated by three feet of sandstone, for instance, it is very difficult to determine how much coal can be extracted from each seam.
- (5) The mining method. In a particular seam a higher percentage of coal can generally be extracted by the longwall system¹⁾, or by a system of pillar extraction²⁾, than by the bord and pillar system more commonly used.
- (6) Condition of roof. The strata in immediate contact with the coal

1) Another method of mining known as "long-walling" has been introduced in some collieries. In order to practise this type of mining, certain conditions pertaining to roof strata, depth below surface, and thickness of seam are necessary, and, in addition, a more disciplined mining technique is required, but it is more efficient in that little coal is wasted. Extraction of up to 90 per cent of the coal is possible.

Briefly, long-walling consists of removing all the coal in a working face and filling up the empty space called "goaf" (from the Welsh 'ogof' meaning a hollow) with waste materials to hold up the roof.³⁴⁷

2) By this method, the roof of the workings is supported by metal supports, the whole seam taken out, and the roof is allowed to collapse as the working face advances.

seam are often either intrinsically weak, or are subject to rapid weathering when exposed to the mine atmosphere. Coal which is more resistant to deterioration is, therefore, frequently left in the roof.

- (7) Depth of burial. Costs of mining generally increase with depth of burial.
- (8) Mining legislation. The proportion of coal that can be extracted is also influenced by mining laws. For instance, the amount of coal to be left to prevent damage to roads, railways and other structures on the surface is important.
- (9) The price of coal. This is one of the most important factors influencing the extraction ratio. If the price of coal was substantially increased, use could perhaps be made of mechanical supports, instead of leaving coal pillars behind for this purpose.
- (10) The demand for coal. In one particular mine, it was calculated by the company that if they continued to supply the general market, as they are at present, they would only mine 8 per cent of the total in situ reserves on the property, whereas 67 per cent of the in situ reserves could be extracted if they were also to supply a power station or synthetic oil plant.³³⁷
- (11) Quality of the coal. The percentage of coal mined also depends on the quality of the coal, and the demand for various qualities of coal. There is, for instance, at present little or no demand in the Republic for lean coal.

To these factors may be added such items as costs and availability of labour, technical know-how and the state of the general economy of the country.

According to the report, not all coal that is, or can be, mined is even utilized. Coal supplied to consumers other than power stations or synthetic oil plants is generally washed, and, in this process, as much as 45 per cent of the material may be discarded, in the case of coking coal. The percentage of material lost by washing varies from one colliery to another, and is dependent on the quality of the coal in situ, the demand for various grades of coal, and the specifications for coal required by various consumers. It is also a function of company policy and the prices of various grades of coal. In 1967, a total of about 7.3 million tons of waste was dumped in the Republic. An appreciable percentage of this material represents combustible matter which could be burnt in a power station, but, under present conditions, it is uneconomical to recover this material.

Various consumers demand different size-fractions of coal. In the process of mining, coal of various grades is produced, but not necessarily in the proportions for which there is a demand. If the demand for the finer fractions is higher than the production, the problem can to some extent be overcome by crushing the coal. If, on the other hand, the production of fines is more than the demand, the finer size ranges are dumped. In 1967, about 800,000 tons of duff coal was dumped in the Republic. The decrease in coal consumption by the South African Railways, and the policy of Escom to obtain their supplies from captive collieries have resulted in difficulties for the commercial collieries with regard to the disposal of certain size ranges of coal.

It should, therefore, be obvious from the above that a third figure for coal reserves, namely saleable, usable or marketable reserves, should be calculated as representing that portion of the total coal reserves that is likely to be utilized.

The figures for extractable and saleable coal reserves are, of course, not fixed, as in the case of in situ reserves. These estimates are basically dependent on the price of coal, the availability of competitive energy sources, the demand pattern for coal, and the policy of the mining companies and of the government.

Table 16 presents South Africa's coal reserves as established by the investigation conducted by the Coal Advisory Board.^{33/} This table, in addition to providing an indication of the geographical distribution of reserves, also classifies reserves by quality, as expressed in its distribution of calorific value in lb./lb.¹⁾

According to this report, therefore, only 47.6 per cent of the total in situ reserves is regarded as extractable. Of the total extractable reserves, some 91.6 per cent is regarded as saleable, which means that only 43.2 per cent of the in situ reserves is regarded as saleable. The reasons for the relatively low percentage of coal which is likely to be utilized are that the percentage extraction in the Free State and South Rand fields is expected to be very low. Of the total in situ reserves, 4.1 per cent is present in Natal, 17.4 per cent in the Free State - South Rand field, and 78.5 per cent in the south-eastern Transvaal coalfields.

1) The lb./lb. unit indicates the number of pounds of water that can be evaporated by one pound of fuel, at atmospheric pressure, at 212 degrees Fahrenheit. Approximately 970 Btu are required to evaporate one pound of water at 212°F, hence, to convert lb./lb. units to Btu, multiply the former by 970.

TABLE 16: THE COAL RESERVES¹⁾ AND RESOURCES OF SOUTH AFRICA (1967)³⁷

AREA	DEFINITION OF RESERVES	COAL IN SITU x 10 ⁶ SHORT TONS CVin lb./lb.					EXTRACTABLE COAL x 10 ⁶ SHORT TONS CVin lb./lb.					SALEABLE COAL x 10 ⁶ SHORT TONS CVin lb./lb.					TOTAL COAL x 10 ⁶ SHORT TONS		
		9-11	11-12	12-12.5	12.5-13	> 13	9-11	11-12	12-12.5	12.5-13	> 13	9-11	11-12	12-12.5	12.5-13	> 13	COAL IN SITU	COAL EXTRACTABLE	COAL SALEABLE
RESERVES OF COAL																			
I. Natal: Northern Coal- field + Kliprivier Coalfield + Wakker- stroos Pit Relief:	(a) Reserves in commercial collieries	65.0	82.2	35.2	43.3	-	54.1	64.6	23.1	32.0	-	49.2	-	20.6	7.9	79.5	225.7	173.8	157.2
	(b) Reserves in captive collieries	-	114.0	-	-	-	-	62.7	-	-	-	-	57.1	-	-	-	114.0	62.7	57.1
	(c) Reserves in prospected areas	102.1	443.7	182.0	22.0	-	74.9	323.3	95.3	13.2	-	67.7	230.6	64.7	65.7	17.5	749.8	506.7	446.2
	TOTAL (a) to (c)	167.1	639.9	217.2	65.3	-	129.0	450.6	118.4	45.2	-	116.9	287.7	85.3	73.6	97.0	1,089.5	743.2	660.5
II. O.F.S.: Vereeniging - South Rand:	(a) Reserves in active collieries	2,011.9	-	-	-	-	316.8	-	-	-	-	316.0	-	-	-	-	2,011.9	316.8	316.0
	(b) Reserves in captive collieries	827.5	-	-	-	-	302.2	-	-	-	-	296.3	-	-	-	-	827.5	302.2	296.3
	(c) Reserves in prospected areas	1,779.3	-	-	-	-	562.7	-	-	-	-	518.7	-	-	-	-	1,779.3	562.7	518.7
	TOTAL (a) to (c)	4,618.7	-	-	-	-	1,181.7	-	-	-	-	1,131.0	-	-	-	-	4,618.7	1,181.7	1,131.0
III. South-Eastern Trans- vaal: Witbank - Middelburg - Bethal - Belfast - Carolina - Ermelo - Standerton - Volksrust:	(a) Reserves in collieries:																		
	(i) Seams mined at present	67.8	605.5	733.6	244.7	126.4	28.1	357.5	511.8	154.5	88.5	-	126.8	325.3	444.9	79.6	1,778.0	1,140.4	976.6
	(ii) Seams mineable, but not mined at present	1,272.0	1,353.2	81.7	-	-	780.5	885.7	45.3	-	-	501.6	576.7	354.5	53.0	-	2,706.9	1,711.5	1,485.8
	(b) Captive collieries	2,011.7	1,109.4	-	-	-	1,107.6	617.4	-	-	-	1,104.4	617.4	-	-	-	3,121.1	1,725.0	1,721.8
	(c) Prospected areas (proved reserves)	8,730.5	1,861.2	363.9	133.2	-	3,618.0	980.3	217.3	92.2	-	3,118.1	897.3	302.2	275.0	40.6	11,088.8	4,907.8	4,833.2
	(d) Prospected areas (not fully prospected)	1,500.0	-	-	-	-	800.0	-	-	-	-	600.0	-	-	-	-	1,500.0	800.0	600.0
	TOTAL (a) to (d)	13,582.0	4,929.3	1,179.2	377.9	126.4	6,334.2	2,840.9	774.4	246.7	88.5	5,324.1	2,218.2	982.0	772.9	120.2	20,194.8	10,284.7	9,417.4
	(e) No. 5 seam (Blend Coking and High- grade Bituminous)	-	373.0	47.7	170.3	9.5	-	254.7	30.1	118.1	6.5	-	94.8	99.1	39.8	115.2	600.5	409.4	348.9
	TOTAL (a) to (e)	13,582.0	5,302.3	1,226.9	548.2	135.9	6,334.2	3,095.6	804.5	364.8	95.0	5,324.1	2,313.0	1,081.1	812.7	235.4	20,795.3	10,694.1	9,766.3
TOTAL I TO III	Reserves mineable in present mining areas..	18,367.8	5,942.2	1,444.1	613.5	135.9	7,644.9	3,546.2	922.9	410.0	95.0	6,572.0	2,600.7	1,166.4	886.3	332.4	26,503.5	12,619.0	11,557.8
POTENTIAL RESERVES																			
IV. Natal:	Possible future (not regarded mineable at present)	-	-	21.0	-	-	-	-	21.0	-	-	-	-	21.0	-	-	21.0	21.0	21.0
	V. O.F.S. - South Rand:	Possible future (if longwall mining successful)	608.0	-	-	-	-	801.9	-	-	-	-	801.9	-	-	-	608.0	801.9	801.9
VI. South-Eastern Trans- vaal:	(a) Defunct mines (reserves left behind)	24.0	74.5	-	-	-	16.8	51.5	-	-	-	-	48.8	4.9	-	-	98.5	68.3	53.7
	(b) Other possible future	340.0	544.3	-	-	-	188.7	357.0	-	-	-	12.7	528.4	-	-	-	884.3	545.7	541.1
TOTAL I TO VI		19,339.8	6,561.0	1,465.1	613.5	135.9	8,652.3	3,954.7	943.9	410.0	95.0	7,386.6	3,177.9	1,192.3	886.3	332.4	28,115.3	14,055.9	12,975.5
VII. Waterberg Coalfield:	(a) Open cast reserves. Stripping ratio > 1 : 1	2,458.0	-	-	-	-	2,213.0	-	-	-	-	863.0	863.0	-	-	-	2,458.0	2,213.0	1,726.0
	(b) Open cast reserves. Stripping ratio 1 : 1 to 1 : 4	3,272.0	-	-	-	-	2,945.0	-	-	-	-	1,148.0	1,148.0	-	-	-	3,272.0	2,945.0	2,296.0
	(c) Conventional mining reserves	2,011.0	1,083.0	-	-	-	1,029.5	369.5	-	-	-	-	746.0	267.9	-	-	3,094.0	1,399.0	1,014.0
	Zone 3	412.0	-	-	-	-	200.0	-	-	-	-	100.0	-	-	-	-	412.0	200.0	100.0
TOTAL I TO VIII		27,493.0	7,644.0	1,465.0	614.0	136.0	15,040.0	4,324.0	944.0	410.0	95.0	9,498.0	5,935.0	1,460.0	886.0	332.0	37,351.0	20,813.0	18,112.0
OTHER RESOURCES																			
IX. Natal:	Other coal resources	143.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	143.8	-	-
	X. O.F.S. - Vereeniging:	938.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	938.2	-	-
XI. South-Eastern Trl.:	Other coal resources	41.6	-	-	31.8	-	-	-	-	-	-	-	-	-	-	-	73.4	-	-
	Other coal resources	160.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	160.0	-	-
XII. Indwe Coalfield:	Other coal resources	330.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	330.0	-	-
	Zones 2 and 4. Not considered mineable	680.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	680.0	-	-
XIII. Soutpansberg:	Other coal resources	9,000.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,000.0	-	-
	Conventional mining resources	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1) These totals do not include coking coal reserves in Natal amounting to 150 million tons (saleable) and anthracite amounting to 110 million tons (extractable).

2.2.4 Coal production and quality

South Africa is now among the world's ten largest coal producers. The total value realized for coal, taken from the earliest existing records, to December 1968 is R1,454,659,000 and only gold and diamonds have exceeded this figure. In 1968, South Africa produced 56,934,000 tons¹⁾ of coal. Of this figure, 55,809,000 tons were sold, valued at R97,283,000, at an average pithead price of R1.74 per ton. By comparison, the average pithead prices in the United States and the United Kingdom, for that year, were R5.00 and R10.70 respectively. Thus, South Africa's coal is very cheap and, consequently, steam-generated electric power is also relatively less expensive than that of most other countries.

South Africa possesses 80 per cent of Africa's coal resources and produces about ninety per cent of the total output on the continent. Of the world's annual bituminous coal and anthracite output, South Africa produces 2.2 per cent; the rest of Africa accounts for 0.2 per cent.^{22/}

In terms of Europe's best, the quality of South African coal is, however, indifferent and more than half the coal won has to be upgraded by washing. In order to facilitate a better understanding of the general quality of local coals, it will be necessary to consider briefly the properties of coal.

The properties of coal are mainly determined by four factors, namely, the rank and type of the coal, and the amount and composition of the ash-forming minerals that the coal contains.^{33/}

1) Unless specifically otherwise stated, all tons referred to in this study will be short tons of 2000 lbs.

(i) Rank. This is a measure of maturity, or the degree of metamorphism that the coal has undergone. The main stages of increasing rank are peat, brown coal and lignite, sub-bituminous coal, bituminous coal, semi-anthracite and anthracite. South African coals range from low rank bituminous coal to anthracite, although many so-called South African anthracites are really semi-anthracite.

Many properties are dependent, in greater or lesser degree, on rank, and most of these properties are compared on the pure coal basis, that is, coal free from mineral matter and moisture. The variation of some rank dependent properties are listed below: ^{33/}

Carbon increases with increasing rank.

Oxygen decreases with increasing rank.

Hydrogen decreases in the higher rank lower volatile coals.

Volatile matter decreases with increasing rank.

Moisture decreases with increasing rank, but increases slightly in the anthracite stage.

Calorific value increases with increasing rank, but decreases slightly in the anthracite stage. Due to the opposite trends in calorific value and moisture, the changes in calorific value are much more marked in the moist, mineral matter free basis.

Chemical reactivity and liability to spontaneous combustion decrease with increasing rank.

Coking properties are absent in low rank coals, reach a maximum in medium volatile bituminous coals, and disappear again at or before the semi-anthracite stage.

Strength is reasonably constant until the medium volatile bituminous stage, when it falls, and increases again in the anthracite stage, where the hardest coals are found. The lower rank coals are subject to weathering and tend to slack and soften on exposure.

- (ii) Type. South African coals can be typified as bright or dull, or intermediate stages or mixtures between bright and dull coal. Bright coals are higher in hydrogen, volatile matter and calorific value, and lower in carbon than the corresponding dull coals. Selected bands of bright and dull coal from the same seam, at the same place, can show differences of one per cent in hydrogen, ten per cent in volatile matter, one pound per pound in calorific value, and possibly two per cent in carbon, measured on the pure coal basis. Truly dull coals never have any coking properties, even if the rank is suitable.
- (iii) Minerals. Minerals act as diluents of the coal substance, as does moisture. South African coals contain fairly large proportions of minerals, the ash contents of saleable coal ranging from about 7 per cent for the better quality anthracites to nearly 30 per cent for some Orange Free State coals. The composition of the mineral matter is important, as high concentrations of carbonates and pyrites lead to low ash fusion temperatures, and the sulphur oxides formed from pyrites can cause corrosion and increase atmospheric pollution. Phosphorus and other minor components can cause external boiler deposits and phosphorus is undesirable in coals for metallurgical uses.

The Fuel Research Institute regularly analyse samples taken from the production of all the various individual collieries, and average results over the course of a calendar year are published.³⁶⁷

From these results, the quality of coal in the various producing coalfields can be observed:³³⁷

- (i) Witbank. On the No.5 seam, four collieries produce blend coking coal for Iscor as sole or main product, and three collieries towards the west and south - where the rank of the coal is lower - produced unwashed coal for the general market in 1967. Four collieries, situated in the south-western portion of the coalfield and mining the No.4 seam, produce coal of a relatively low rank. One of these collieries supplies coal mainly for a nearby power station. Two collieries mining the No.2 seam, one of which also mines the No.4 seam, supply coal to nearby power stations. Two collieries in the far east and west produce coal that is rather lower in rank.
- (ii) Ermelo - Belfast. One colliery at Belfast and four in the Ermelo coalfield supply the general market. Two collieries south-east of Ermelo supply power station coal.
- (iii) Heidelberg and Orange Free State. These coalfields provide coal of similar rank and quality. Most of the coal produced is used in power stations, but some coal enters the general market - mostly sized coal and often washed.
- (iv) Natal. Whereas all the coals in the Transvaal and Orange Free State are medium to low rank bituminous, the smaller Natal fields are better, producing anthracites, coking coal and high quality bituminous coal.

The saleable reserves as provided in Table 16, are given as washed coal.³³⁷ In other words, the reserves are classified according to the average quality of the washed product. It is possible, in some cases,

to produce a product with a higher calorific value by changing the washing procedure, but this results in a net loss of coal. The figures in Table 16 refer to the present quality of washed coal in existing mines, and to the product which is expected to be produced in prospected areas. In the case of most captive collieries and other mines where the coal is not washed, the saleable quality is, of course, the same as that of extractable quality. On this basis, the percentages of saleable reserves in the various quality categories are as follows:

<	-	11	1b./1b.	56.9%
11	-	12	1b./1b.	22.5%
12	-	12.5	1b./1b.	10.1%
12.5	-	13	1b./1b.	7.7%
Above 13			1b./1b.	2.8%

These calculations show that a large percentage of the Republic's coal reserves is of a relatively poor quality.

2.2.5 Sales, inland demand and external trade of coal

Considerable disagreement exists about the exactness of the annual coal consumption figures of the Republic. The report of the Coal Advisory Board, recently published, discusses available estimates and came to the conclusion that there are wide differences between different sources.^{33/} The problem stems from the fact, it seems, that even to this day no organised attempt has yet been made by the industry to systematically collect and publish data pertaining to the total annual coal consumption, as well as to total consumption broken down by sector.

Under these circumstances, in order to preserve some measure of objectivity, one is forced to approximate the required data as far as is

possible by using officially published statistics. Table 17 is, therefore, a summary of all the time series officially available on annual sales, imports, exports and bunkers of coal. A detailed discussion of sources of data is left over for chapter three, which deals with the construction of the historical energy balances of South Africa.

As indicated in Table 17, annual consumption is estimated by adding imports to sales and subtracting, from this total, the combined tonnages of exports and bunkers.

It needs to be pointed out that total annual sales of coal are smaller than total production, as considerable quantities, either unsuitable for consumption or for which there are no immediate demand, are dumped. Imports are so small that it hardly warrants any further discussion.

The decreasing series on the demand for bunkers in recent years reflects the displacement of coal by oil as a source of energy for ocean going vessels.

Coal for the export trade reached a peak of about 4 million tons during the war, but has since declined by 1968 to a little over a million tons. The reasons for the poor export performance are the relatively low quality of South African coal, prohibitive rail transport costs from the inland coalfields, political factors, the substantial capital requirements of bulk export facilities at harbours, and an overloaded railway system, which, at times, is finding it difficult to cope with the domestic demand for coal. To this may be added the natural reluctance of countries to rely on imported sources of energy in view of the promising progress made with the development of new sources of energy - notably nuclear power.

Over the last number of months, however, promising statements have come from various sources on the possibilities of stepping up exports of coal. Up to the present, the exports of coal have largely been left to the

TABLE 17: TOTAL COAL CONSUMPTION IN THE REPUBLIC OF SOUTH AFRICA
AND SOUTH WEST AFRICA 1910 - 1968

('000 TONS)

YEAR	SALES	IMPORTS	EXPORTS	BUNKERS	TOTAL INLAND CONSUMPTION
	(1)	(2)	(3)	(4)	(5)
1910	7,122	-	139	1,336	5,637
1911	7,595	68	83	1,441	6,139
1912	8,117	75	167	1,426	6,599
1913	8,801	58	856	1,456	6,547
1914	8,478	77	651	1,360	6,544
1915	8,281	28	507	1,306	6,496
1916	10,008	14	566	2,164	7,292
1917	10,383	15	539	2,348	7,511
1918	9,877	10	1,211	1,290	7,386
1919	10,266	10	1,094	1,433	7,749
1920	11,473	8	1,301	1,858	8,322
1921	11,397	16	1,795	1,643	7,975
1922	9,734	14	1,478	1,436	6,834
1923	11,917	12	1,904	1,816	8,209
1924	12,492	13	1,925	1,821	8,759
1925	13,000	18	1,760	1,971	9,287
1926	13,734	23	2,354	1,964	9,439
1927	13,303	6	1,805	1,840	9,664
1928	13,403	9	1,650	1,656	10,106
1929	13,913	-	1,836	1,737	10,340
1930	13,106	8	1,415	1,466	10,233
1931	11,639	1	1,051	1,018	9,571
1932	10,650	-	721	752	9,177
1933	11,528	-	879	912	9,737
1934	13,117	-	1,036	995	11,086
1935	14,608	15	1,273	1,188	12,162
1936	15,996	25	1,178	1,365	13,478
1937	16,718	27	888	1,261	14,596
1938	17,536	26	993	1,258	15,311
1939	18,106	35	1,165	1,022	15,954
1940	18,934	54	947	1,485	16,556
1941	20,213	47	1,089	1,681	17,490
1942	22,102	50	1,426	1,919	18,807
1943	22,287	52	2,260	885	19,194
1944	24,907	53	4,104	844	20,012
1945	25,466	48	4,212	852	20,450
1946	25,634	72	3,523	798	21,385
1947	25,415	56	2,908	677	21,886
1948	25,968	65	1,893	627	23,513
1949	27,427	74	2,044	650	24,807
1950	28,665	42	2,831	416	25,460
1951	28,768	54	1,892	268	26,662
1952	30,038	93	932	172	29,027
1953	30,570	32	1,326	87	29,189
1954	30,844	2	1,245	74	29,527
1955	33,061	106	772	-	32,395
1956	35,570	45	723	-	34,892
1957	37,687	56	702	-	37,041
1958	39,940	62	738	-	39,264
1959	39,193	30	566	-	38,657
1960	41,962	-	1,048	-	40,914
1961	42,363	-	1,164	-	41,199
1962	45,210	65	1,814	-	43,461
1963	46,140	55	1,540	-	44,655
1964	48,622	108	1,526	-	47,204
1965	52,452	63	1,480	-	51,035
1966	51,722	29	1,226	-	50,525
1967	53,271	4	1,385	-	51,890
1968	55,700	30	1,395	-	54,335

anthracite producers. It is indicated that many collieries in France, Germany, Belgium and Holland have closed down due to increased operating costs. At the same time, the steel industries of Europe and Japan are booming. New techniques have been introduced into steel making and these, requiring heavy introduction of anthracite for sintering purposes, can open up export possibilities for South African anthracite. In addition, plans have been announced in the Press about exporting substantial quantities of coking coal to Japan and elsewhere, provided adequate harbour facilities can be obtained at Lourenco Marques, and suggestions have been made about the building of a rail link between Witbank and Richards Bay for the export of coal.

Whether these plans will ever come to fruition remains to be seen. A number of priorities will have to be established. It is doubtful, for instance, to what extent the country's strained resources will be able to sustain the development of the Saldanha Bay iron ore scheme and the Richards Bay scheme, simultaneously. It is also now known that the country's coal reserves are by no means as vast as previously assumed, and that the resources of coking coal are even smaller. Careful studies will have to be made as to the feasibility of exporting raw iron ore, albeit locally in abundance, and high quality coal, especially coking coal, which is not in abundant supply, instead of first upgrading the raw material industrially. In chapter five, however, these problems will be discussed in further detail.

From Table 17 it is also clear that inland consumption of coal has grown ten-fold from 1910 to 1968, or at an average annual rate of 4 per cent. Over the last three years of the analysis, however, from 1965 to 1968, the average annual increase has only been of the order of 2.1 per cent.

2.2.6 The historical pattern of demand for coal

The total annual coal consumption, as established in the last column of Table 17, is subsequently broken down by individual consumption sector in Table 18. Discussion of the sources of data used is a lengthy procedure and will again be left over for chapter three. At this stage, it needs to be pointed out that sources of all statistics which are quoted in the remainder of this chapter, and which are also used for the construction of the energy balances, will be discussed in chapter three.

Available sources do not allow a complete breakdown of consumption prior to 1928, with the exception of consumption by Escom, railways and mines. Table 19 further provides the percentage distribution of consumption by sector.

Table 18, read in combination with Table 19, shows that the electricity industry is by far the largest consumer, consuming more than half the total demand in 1968. Second largest consumer is the South African Railways with 11.9 per cent, followed by industrial consumers excluding Sasol (11.1 per cent), coke producers (10.8 per cent), domestic consumers (6.4 per cent), Sasol's oil from coal plant, excluding power generation and pipeline gas production, (3.6 per cent), mines (2.8 per cent), and coal gas producers (0.7 per cent).

From Table 19 it is also evident that an important structural change in demand has taken place from 1910. Whereas the South African Railways and the mining sector, between them, accounted for 53 per cent of total demand in 1928, this percentage had decreased to 14.7 per cent in 1968. The reason for this is that these two sectors have become two of the largest consumers of electricity in the country. In the case of the former, it has happened because of the electrification of the country's

TABLE 18: COAL CONSUMPTION BY SECTOR IN THE REPUBLIC OF SOUTH AFRICA
AND SOUTH WEST AFRICA, 1910 - 1968

('000 TONS)

YEAR	ELECTRICITY GENERATION			RAILWAYS	COKE PRODUCERS	COAL GAS PRODUCERS	MINING	SASOL	INDUSTRY	DOMESTIC	TOTAL INLAND CONSUMPTION
	ESCOM	OTHER	TOTAL								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1910	-			-			-				5,637
1911	-			1,463			2,609				6,139
1912	688			1,672			2,472				6,599
1913	901			1,895			2,535				6,547
1914	962			1,929			2,108				6,544
1915	1,063			1,875			2,241				6,496
1916	1,140			2,305			2,507				7,292
1917	1,182			2,382			2,537				7,511
1918	1,257			2,272			2,471				7,386
1919	1,250			2,470			2,516				7,749
1920	1,262			2,746			2,339				8,322
1921	1,272			2,432			2,099				7,975
1922	1,119			2,258			1,672				6,834
1923	1,435			2,645			2,150				8,209
1924	1,576			2,790			2,206				8,759
1925	1,603			3,107			1,740				9,287
1926	1,674			3,126			2,164				9,439
1927	1,760			3,107			2,128				9,664
1928	1,935	929	2,864	3,264		10	2,113		268	1,587	10,106
1929	2,086	999	3,085	3,291		11	2,131		260	1,562	10,340
1930	2,166	899	3,065	3,048		12	2,050		280	1,778	10,233
1931	2,237	599	2,836	2,699		14	2,031		270	1,721	9,571
1932	2,388	599	2,987	2,463		16	1,842		260	1,609	9,177
1933	2,542	499	3,041	2,832	200	18	1,847		250	1,549	9,737
1934	2,831	638	3,469	2,991	350	20	1,996		591	1,669	11,086
1935	3,152	768	3,920	3,336	400	28	2,109		580	1,789	12,162
1936	3,584	898	4,482	3,581	450	40	2,250		775	1,900	13,478
1937	3,844	1,028	4,872	4,065	540	62	2,278		759	2,020	14,596
1938	4,176	1,182	5,358	3,612	672	68	2,441		1,025	2,135	15,311
1939	4,409	1,382	5,791	3,888	728	72	2,384		1,056	2,035	15,954
1940	4,626	1,482	6,108	4,108	704	74	2,414		1,003	2,145	16,556
1941	4,904	1,612	6,516	4,258	812	78	2,453		1,123	2,250	17,490
1942	5,112	1,712	6,824	4,449	1,126	87	2,443		1,513	2,365	18,807
1943	4,978	1,713	6,691	4,545	1,136	94	2,378		1,876	2,474	19,194
1944	5,164	1,813	6,977	4,716	1,162	95	2,445		2,069	2,548	20,012
1945	5,309	1,893	7,202	5,012	1,205	102	2,497		1,987	2,445	20,450
1946	5,322	1,903	7,225	5,152	1,225	106	2,898		2,261	2,518	21,385
1947	6,000	2,203	8,203	5,444	1,307	109	2,468		1,755	2,600	21,886
1948	6,126	2,144	8,270	5,629	1,406	117	2,838		2,386	2,867	23,513
1949	6,366	2,355	8,721	5,563	1,690	134	2,533		3,213	2,953	24,807
1950	6,970	2,544	9,514	5,584	1,775	134	2,226		3,185	3,042	25,460
1951	7,345	2,758	10,103	5,880	2,072	133	1,919		3,422	3,133	26,662
1952	7,841	3,008	10,849	6,327	2,131	144	1,610		4,666	3,300	29,027
1953	8,150	3,330	11,480	6,359	2,221	152	1,560		4,257	3,160	29,189
1954	8,846	3,409	12,255	6,575	2,510	156	1,540	50	3,501	2,940	29,527
1955	9,921	3,678	13,599	6,812	2,510	158	1,650	594	3,912	3,160	32,395
1956	10,680	3,927	14,607	7,052	2,710	158	1,580	833	4,832	3,120	34,892
1957	11,266	3,983	15,249	7,690	2,810	170	1,530	1,091	5,441	3,060	37,041
1958	11,887	4,330	16,217	8,141	2,930	166	2,223	1,182	5,355	3,050	39,264
1959	12,730	4,311	17,041	7,356	3,460	155	1,560	1,290	4,525	3,270	38,657
1960	13,793	4,331	18,124	7,239	3,610	159	1,520	1,327	5,725	3,210	40,914
1961	14,245	4,605	18,850	6,899	3,780	152	1,540	1,461	5,397	3,120	41,199
1962	15,383	5,065	20,448	6,950	3,980	179	1,340	1,518	6,056	2,990	43,461
1963	16,227	5,103	21,330	6,906	4,050	189	1,950	1,451	5,529	3,250	44,655
1964	17,256	5,221	22,477	6,846	4,430	174	1,780	1,631	6,456	3,410	47,204
1965	18,438	5,890	24,328	7,402	5,270	172	1,440	1,694	6,779	3,950	51,035
1966	18,720	6,632	25,352	6,873	5,400	209	1,507	1,888	5,626	3,670	50,525
1967	20,180	7,345	27,525	6,395	5,569	275	1,448	1,894	5,161	3,623	51,890
1968	21,092	7,568	28,660	6,459	5,864	366	1,505	1,970	6,017	3,494	54,335

TABLE 19: PERCENTAGE CONTRIBUTION TO TOTAL OF COAL CONSUMPTION BY SECTOR
IN THE REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

YEAR	ELECTRICITY GENERATION			RAILWAYS	COKE PRODUCERS	COAL GAS PRODUCERS	MINING	SASOL	INDUSTRY	DOMESTIC	TOTAL
	ESCOM	OTHER	TOTAL								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1918	17.0			30.8			33.5				
1928	19.1	9.2	28.3	32.3		0.1	20.9		2.7	15.7	100
1938	27.3	7.7	35.0	23.7	4.4	0.4	15.9		6.7	13.9	100
1948	26.1	9.1	35.2	23.9	6.0	0.5	12.1		10.1	12.2	100
1958	30.3	11.0	41.3	20.7	7.5	0.4	5.7	3.0	13.6	7.8	100
1968	38.8	13.9	52.7	11.9	10.8	0.7	2.8	3.6	11.1	6.4	100

rail system, whereas the mining sector is today by far the largest consumer of electricity in South Africa. The electricity requirements of these two consumers are almost exclusively supplied by Escom. The rapid increase in market share of Escom, namely from 19.1 per cent in 1928 to 38.8 per cent in 1968, is therefore partly the result of these trends.

The demand for coking coal has grown from 4.4 per cent of the total in 1938 to 10.8 per cent in 1968, a fact which reflects the growth in the Republic's metallurgical industries.

The industrial demand for coal showed a rapid increase in share of the market between 1928 and 1958 but thereafter declined relatively. It therefore seems that substitution tendencies also had an effect on the coal demand in this sector.

The declining relative importance of the domestic coal market, and the rapid growth of electricity demand in this sector, are in accordance with the world wide trend towards consumption of more sophisticated forms of energy, given rising standards of living.

The growth of the South African coal industry has been determined, firstly, by the relative proximity of vast deposits of coal to the Southern Transvaal gold mining and industrial complex, and, secondly, by Escom's policy of siting their power stations next to captive collieries to achieve the advantages of backward integration.

These factors have had the effect of converting the coal industry into one with a dual production and marketing structure, in order to serve two different sources of demand. Consequently, some mines produce coal only for single power stations, the major growth point in the coal industry, while the rest are dependent upon other sources which may use substitutive forms of energy to an increasing extent when planning expansion.

(i) Electricity generation

In 1968, 28.7 million tons of coal were used in the Republic solely for purposes of electricity generation. Of this total, Escom consumed about 21 million tons, while the remaining 7.6 million tons were accounted for by about 25 independent municipal producers, and mining and industrial self producers, including the Sasol power station.

Inevitably, South African industry has grown up, not so much on a diet of cheap coal, but on cheap electricity generated from it. Escom currently generates about 80 per cent of the Republic's power, which in turn represents half the electricity generated in the whole of Africa. In the next section of this chapter the electricity industry will be discussed in fuller detail.

(ii) The South African Railways

The railways' share of total consumption dropped rapidly from 1928 onwards, due to electrification and the increasing use of diesel locomotives. It should, however, be pointed out that a change from coal burning to electric locomotives simply means a change in the method of coal utilization. The use of diesels is limited, and restricted mainly to areas where water is scarce.

(iii) Industry

Coal consumed by secondary industry has risen steadily, in absolute as well as relative terms, until about 1964. Since that year, however, increasing substitution by fuel oil has taken place, especially in the coastal areas, far away from the coal fields, where the price of coal is often in excess of four times the pithead price.

The average calorific value of coal sold in these coastal areas is about 12.5 lb./lb. and, if under these circumstances markets have been lost to oil, the coal industry should not offer low-grade coal in these areas.³³⁷

Trends in fuel demand can reflect important structural changes in the economy. Over the last decade or so, the demand for materials, fuel and labour by manufacturing industries has placed correspondingly heavy demands upon the economy's available resources. Although manufacturing has quantitatively become the major growth sector in the economy, the qualitative changes induced are even more important in the discussion of fuel requirements. Import substitution has become a most important causal factor in stimulating dynamic growth in those industries which are characterized by a high degree of technological sophistication. Consequently, the form of energy required must be capable of being utilized with a high degree of efficiency and selective control. Coal-burning equipment may not always satisfy these requirements as well as electricity and oil might, with the result that the demand for coal as an industrial fuel has tended to lag behind that of electricity.³³⁷

(iv) Coking coal

Coking properties are not present in all coals. For coke to be formed, the coal - or the major portion of the coal - must develop plasticity during heating. Only the bright coal or vitrinite, assisted by the minor component exinite, is capable of developing plasticity, and then only if of suitable rank. Low rank coals, as are found in the Orange Free State and the major portion of the Southern Transvaal, and the high rank low volatile coals of Natal, exhibit little or no tendency towards

the plasticity of the bright brands, and thus have virtually no coking properties, especially as much of the coal is mainly dull and contains a lot of inert material. Coking properties are at their best in the highest rank high volatile coals and the medium volatile coals.

Coal with reasonably to well developed coking properties is restricted to the vicinity of Witbank, and the Waterberg and Soutpansberg coalfields of the Transvaal, and to Natal.³³⁷

The tonnage of coking coal used prior to 1934 was relatively small, and it was not until Iscor started producing in that year that the requirements for coking coal in the Republic began to show a steady increase. The iron and steel industry is the major consumer of coke in the Republic, but small quantities are used in the explosives industry, for the manufacture of carbides and for general use.

Concern about the country's coking coal reserves, and the need for conservation, dates back a long time, and is a subject that has been discussed at great length in the report of the 1946-7 Coal Commission.³⁷

The Republic's reserves of coking coal are small relative to the demand; consequently, straight coking coals are mixed with blending coal in the ratio of about 40:60 in the interest of conservation. Research is being done on the production of artificial coke, and, on a laboratory scale, the results are reported to be promising. Experiments have also been done in the use of powdered coal, but only one firm in the United States appears to be persevering with this work. The reason for this is thought to be that a very high capital investment is necessary for the preparation, storage, handling and injection of powdered coal. Oil or gas injection can extend the reserves

of coking coal.³³⁷

(v) Domestic consumers

Coal sold through merchants to domestic consumers, including households and small commercial undertakings such as hotels, restaurants and hospitals, is mainly used in coal stoves or boilers for cooking, steam raising or space heating.¹⁹⁷

Among the reasons for the constant decline in market share of coal used for these purposes are the greater versatility of alternative sources of energy, such as electricity, oil and gas, adverse trends in relative prices, interruption of supplies or fear of it, constant expansion of the electricity supply network including the electrification of Bantu residential areas, and matters of convenience such as the need for storage etc. Legislation passed in 1965 to combat air pollution may have a detrimental effect on domestic usage of coal in future, although steps have been taken by the coal industry to provide their customers with technical advice and service to combat pollution.

(vi) Oil from coal (Sasol)

It needs to be pointed out that the consumption figures for Sasol, as indicated in column (8) of Table 18, exclude coal used for electricity generation and for the production of Gascor pipeline gas. The latter refers to coal gas which is reticulated to Reef consumers by pipe-line. The figures quoted above, therefore, refer to the coal inputs for the production of synthetic petroleum and allied petrochemical substances. The consumption of coal in Sasol's power plant is included in column (2) of Table 18, while the coal which is subsequently gasified for reticulation purposes is included in column (6), under the heading of Coal Gas Producers. This

way, a more homogeneous classification of the sectoral distribution of total coal consumption is obtained.

It is clear from column (8) of Table 18 that the demand for coal for purposes of producing synthetic petroleum and allied products is small in relation to the total coal consumption. The reasons for this are possibly the prohibitive capital requirements of installations of this nature (Sasol is the only commercial enterprise of its kind in the world), and the fact that the conventional petroleum industry still holds a competitive edge over the synthetic processes that have been developed. This, however, by no means belittles the important contributions of Sasol to the chemical industry in South Africa.

(vi) Mines

The mining sector which once represented a very important outlet for coal (33.5 per cent of total demand in 1910) today accounts for a very modest share of the total (2.8 per cent in 1968). This is mainly due to the displacement of coal by electricity as a source of power for mining equipment. It can, therefore, be stated that the mines have changed from a major direct consumer to a very important indirect consumer of coal.³³⁷

(vii) Coal gas producers

The historical series under this heading includes the consumption of coal by five town gas producers, and one undertaking producing coal gas solely for the industrial market. Among the five town gas producers, some of them private companies, number undertakings at Johannesburg, Springs, Cape Town, Port Elizabeth and Grahamstown. The remaining producer, Gascor, is an affiliate of Sasol and produces coal gas for reticulation to Reef industrial consumers. The Springs Municipal Gas Works, commissioned in March 1953, ceased production in 1966 when its

reticulation network was taken over by Gascor.

Since 1968, there has been a sharp drop in coal carbonised by the Grahamstown Gas and Coke Company Limited due to implementation of a conversion programme from coal gas to liquid petroleum gas. Officials of this Company expect to complete the conversion in 1971, when the manufacture of gas from coal will cease altogether.

The Port Elizabeth Municipal Gas Works, similarly, ceased the production of town gas from coal during May 1967, and has since been using a petroleum derivative as a basic feedstock. Authoritative opinion has it that the use of coal for the manufacture of town gas in South Africa (excluding Gascor) will diminish over the next few years, and will ultimately be replaced entirely by oil.

From Table 19, it is evident that the use of coal for this purpose is relatively small in relation to the total. Of the total consumption of 366,000 tons in 1968, Gascor alone contributed 220,000 tons, or 60 per cent, the Johannesburg Municipal Gas Works 115,000 tons (31 per cent) and The Cape Town and District Gas Light and Coke Company Limited 27,000 tons (7 per cent).

The discovery of economic quantities of natural gas could have a significant effect on the entire coal consumption for purposes of producing coal gas. While it is unlikely that consumption on the Reef will be affected by a gas find on the continental shelf, on account of the high transport cost involved, an inland discovery could, of course, materially change the picture.

2.2.7 The average prices of South African coal

In terms of price, South Africa's coal is among her biggest blessings. The seams are shallow (from 50 feet to 800 feet below surface and vary in

width from 3 feet (the narrowest considered economically mineable) to as much as 200 feet at Witbank.¹⁴⁷ Relative ease of underground exploitation, coupled with low labour costs, have yielded pithead prices that are among the lowest in the world.

As an example, the maximum controlled selling price from Transvaal pits - other than power station suppliers which operate on cost - plus prices - was R1.52 per ton of coal, prior to October 1968, for coal of a calorific value of 11600 Btu/lb or more. This is far below comparable prices of R5.00 plus in the U.S., and between R6.00 and R11.00 in Britain, for that year.

The prices at which coal, qualifying for price control, is sold are subject to maxima imposed, and are periodically adjusted by the Government. In October 1968, for instance, a price increase of 20 cents a ton³⁸⁷ for Transvaal coal above 11600 Btu/lb was granted by the Price Controller, raising the controlled price to R1.72 per ton. For price control purposes, a distinction is made between the various grades, i.e. duff coal and other (high-grade) coal. The controlled prices for Natal coal are generally higher, almost twice the level of Transvaal and Orange Free State coal.

Anthracite and smithy coal is not subject to price control, and there is also no control on export prices of coal. The latter category is only subject to governmental quality control.

Delivered prices, however, vary with railage costs which are high. In the Cape, more than 1000 miles from the Witbank coalfields, the price of coal is relatively high, the rail cost per ton being in the region of R4 to R5, and the delivered price is, consequently, four to five times the pithead price, depending on the trade category.

For the purposes of this study it is essential to quantify historical trends in the average prices of coal bought and consumed at the final level. This is important from the point of view of considering shifts in relative prices of different energy-producing agents as a possible explanation of substitution tendencies. It is equally important, also, to assess price trends of the product at the level of final consumption, i.e. coal used by the final consumer in its original form, excluding its use in the conversion sector, that is, for the production of electricity or gas. Given the South African energy environment, it will be necessary to establish the average price trends of coal and other energy-producing agents at the level of final consumption, because it is in the sector of final demand where the motivational factors of consumers, including considerations of price, convenience, etc., determine preference of coal, oil, electricity or gas as sources of energy. Preference for coal, or any other source of energy, in satisfying primary demands of the conversion industries, is determined, for the greater part, by factors other than those mentioned above, and include considerations of availability, national policy etc.

It is also necessary to observe that a time series indicating trends in the final selling prices of coal, so established, by nature has to be a series relating to the average price of coal, over a number of different end use sectors and geographical regions, for a particular year. It will, therefore, be abstract and theoretical, to a certain degree, but still be very important from the point of view of indicating what the long term trend has been in the average price. This will go a long way towards identifying the factors underlying the historical price tendencies and, at the same time, provide a useful platform from which inference regarding future price trends can be made.

The technique of establishing, and using, average national prices of individual sources of energy is a common one and has been applied fruitfully in Britain,³⁹ Holland,²⁰ and the U.S.A.,⁴⁰ in studies of this nature.

Published material on the prices of South African coal is very scant. Average pithead prices are about the only information available on a regular and detailed basis, and also over a fairly lengthy period of time. Details on annual total sales in tons, and in monetary values, can be obtained from official statistical sources,⁴¹⁴² and extend as far back as 1910.

As has been seen, however, the pithead cost, especially in the coastal areas, is a relatively unimportant contributor to total delivered cost, although this contribution is expected to be more substantial to the average delivered cost for the country as a whole. Allowance will, therefore, have to be made for the railage item which is another important component of final delivered cost.

The latter component is derived from statistics available on the total tonnages of coal annually transported by the South African Railways, as well as their income received from this source of revenue. Information of this nature can be extracted from the annual report of the General Manager of Railways and Harbours⁴³ and from Du Plessis,⁴⁴ extending back as far as 1910. This way, an average cost per ton of coal transported by rail can be obtained. Road transport of coal is relatively unimportant in relation to the total.

The only remaining component of some importance to the annual average delivered cost of coal will be the resellers' margin. This is arbitrarily estimated to be about thirty per cent of the average ruling pithead price of coal in any particular year. It is clear that even if this assumption

proves to be grossly incorrect, it will not materially affect the final average selling price in any particular year.

Table 20 provides a summary, therefore, of all these calculations, and establishes a series on the final selling prices of coal in South Africa from 1933 to 1968. It is possible to check the validity of these estimates by taking the geographical distribution of the total coal consumption for 1963⁴⁵⁷ (the only year for which it is available in satisfactory detail), and applying average delivered prices paid in various major geographical centres (which will vary according to the distance the coal is hauled and the pithead location). This was done, and, as an independent control, it was found to be very close to the figures as established in Table 20.

According to the fourth column of Table 20, the average price of coal to final consumers (as expressed in the purchase power of the Rand applicable to the years reflected) increased from R1.47 per ton in 1933 to R4.46 in 1968, or at an average annual increase of 3.2 per cent.

Price control was instituted during the last war, but, in spite of control, annual increases for the period 1960-68 averaged 4.6 per cent, reflecting increased production cost and railage rates.

A clear policy on the prices of South African coal is a priority of the utmost urgency. This policy will have to strike a realistic balance between such opposing objectives as the provision of low cost energy to the economy and the allowance for the maximum possible utilization of the country's coal resources. In the latter respect, it is essential that the coal reserves should not be allowed to be depleted completely, until the time is ripe to draw upon alternative sources of energy, such as nuclear power. Naturally, this is only possible if future demands are known with a reasonable degree of certainty.

TABLE 20: AVERAGE FINAL SELLING PRICES OF COAL, 1933 - 1968

YEARS	PITHEAD PRICE (R PER TON)	RESELLER MARGIN (30% OF PITHEAD PRICE)	RAIL TRANSPORT COST (R PER TON)	FINAL AVERAGE CONSUMER PRICE (R PER TON)	INDEX 1958 = 100
	(1)	(2)	(3)	(4)	(5)
1933	0.50	0.15	0.82	1.47	44.7
1934	0.48	0.14	0.79	1.41	43.0
1935	0.48	0.14	0.76	1.38	42.0
1936	0.50	0.15	0.78	1.43	43.4
1937	0.50	0.15	0.76	1.41	42.9
1938	0.54	0.16	0.75	1.45	44.0
1939	0.54	0.16	0.76	1.46	44.3
1940	0.56	0.17	0.77	1.50	45.5
1941	0.58	0.17	0.77	1.52	46.2
1942	0.60	0.18	0.75	1.53	46.7
1943	0.60	0.18	0.66	1.44	43.7
1944	0.64	0.19	0.66	1.49	45.4
1945	0.66	0.20	0.72	1.58	48.0
1946	0.68	0.20	0.85	1.73	52.8
1947	0.68	0.20	0.91	1.79	54.7
1948	0.70	0.21	0.93	1.84	55.8
1949	0.94	0.28	0.98	2.20	67.1
1950	1.04	0.31	1.13	2.48	75.4
1951	0.94	0.28	1.08	2.30	70.0
1952	0.98	0.29	1.07	2.34	71.2
1953	1.08	0.32	1.17	2.57	78.2
1954	1.04	0.31	1.32	2.67	81.4
1955	1.04	0.31	1.43	2.78	84.7
1956	1.16	0.35	1.47	2.98	90.4
1957	1.14	0.34	1.63	3.11	94.5
1958	1.18	0.35	1.76	3.29	100.0
1959	1.26	0.38	1.75	3.39	102.9
1960	1.31	0.39	1.74	3.44	104.7
1961	1.34	0.40	1.74	3.48	105.8
1962	1.44	0.43	1.86	3.73	113.6
1963	1.47	0.44	1.99	3.90	118.3
1964	1.49	0.45	2.00	3.94	119.8
1965	1.55	0.46	2.09	4.10	124.7
1966	1.56	0.47	2.13	4.16	126.4
1967	1.61	0.48	2.18	4.27	129.8
1968	1.74	0.52	2.19	4.45	135.5

2.3 The electricity industry in South Africa

Until some direct transition from chemical or nuclear energy to electrical energy can be found, the latter will continue to be generated by the so called heat cycle in which heat derived from the energy contained in primary sources such as coal, oil and uranium is changed into mechanical energy, which in turn is used to drive the large alternators. In the Republic, oil has played no significant role in power production, and the main thermal source has been coal, which fortunately is available in substantial amounts in the Transvaal and, to a lesser degree, in the Orange Free State and Natal.

2.3.1 Thermal electricity

2.3.1.1 History

The supply of power on a country-wide basis as a factor in the industrial development of South Africa dates from the early Twenties with the establishment of the Electricity Supply Commission in 1922.⁴⁶⁷

Prior to that date, electricity undertakings which supplied power to industries were actually in existence, but they were of a municipal or private nature, and supplied power in limited areas to consumers within the municipal boundaries or to specific consumers.

The largest of these private suppliers of power, as distinct from municipal suppliers such as Johannesburg, Pretoria, Kimberley and the coastal cities of Cape Town, Port Elizabeth, East London and Durban, was the then Victoria Falls and Transvaal Power Company Limited, on the Witwatersrand, successor to the Rand Central Electric Works which built the first power station for industrial purposes, namely to supply power to the Witwatersrand gold mines. This power station, the Brakpan power

station, which was in use until the Sixties (in reconstructed and enlarged form), is historical on account of the fact that it was the first plant of its kind for industrial purposes in South Africa and was officially opened by President Kruger in 1897.^{46/}

With the establishment of the antecedent company, The Rand Central Electric Works, in 1896,^{47/} and its successor, The Victoria Falls and Transvaal Power Company Limited (the VFP), the foundations were laid in South Africa for the electricity industry and the supply of power in bulk to industries. The VFP was promoted in 1906 and, as its name implied, its purpose was the harnessing of the hydro-electric potential of the Zambesi River at the Victoria Falls to provide power to the Witwatersrand.^{48/} Technical difficulties and high costs prevented the implementation of the hydro-electric scheme, and it was therefore decided to concentrate on steam power.^{47/} It should be noted, however, that this power was being supplied by profit-making undertakings to one (at that time the most important) branch of the South African economy, namely, the gold mining industry; provision to any secondary industries in the area of supply being virtually a side issue.

Already in those early years, however, the provision of power to secondary industries was considered by official sources, because in the Electricity Act of 1910, which 12 years later served as the basis for the Act of 1922, it was stipulated that the Victoria Falls and Transvaal Power Company Limited should provide in its power structure for the supply of 200 MW to industrialists who called for it.

By the passing of the Electricity Act No. 42 of 1922,^{49/} the Electricity Control Board and the Electricity Supply Commission (Escom) were established. With Escom, an instrument was created for the advancement of the country as a whole and, at the same time, the foundations of

the South African industry for the supply of power were laid.

Although, in the Act of 1922, rights were conferred on local authorities to supply power within their municipal areas, the intention, at the time of the establishment of the Commission, already was that the power supply industry was to be a utility undertaking which had to bear the responsibility for supplying electricity to the country as a whole. Consequently, Escom was empowered to expropriate the Victoria Falls and Transvaal Power Company after the expiry of its licence, and this is what happened when Escom purchased the VFP power installations in 1948.

In the Electricity Act of 1958, further details were laid down regarding the generation, distribution and control of electricity in the Republic of South Africa. The Act stipulates that neither Escom nor any other person, company or department of State may supply electricity to other persons except under the authority or permit granted by the Electricity Control Board.⁵⁰⁷ Power may not be supplied outside a defined area and consumers cannot be allowed to take power outside their defined areas. There are four exceptions to this rule:

- (i) Local authorities in the area falling under their jurisdiction.
- (ii) Any department of State if it generates electricity for its own use.
- (iii) Any undertaking with a capacity of less than 500 kilowatts.
- (iv) Any person generating electricity for his own use, and who does not supply more than one million units per annum to other persons.

Authority to supply electricity is always limited to a defined area of supply and the business of supplying electricity is referred to as an "undertaking".

It should be pointed out that, although in principle there is nothing to prevent a company or a person applying for a licence to supply power over a specific area, private supply undertakings are in fact so few and so small that in a general picture they may be disregarded. The great majority of electricity undertakings are controlled by Escom and urban local authorities. Some cities and towns, e.g. Pretoria, Johannesburg, Cape Town, Bloemfontein and Port Elizabeth generate their own power, but most of them obtain bulk supplies of power from Escom.

2.3.1.2. The Electricity Supply Commission (Escom)

Escom was established on the 1st March, 1923, and the Members of the Commission are appointed by the State President. The Commission is a corporate body possessing all the powers necessary for the exercise of its functions of establishing and conducting electricity supply undertakings.

Escom generates and distributes power through its undertakings on a national basis and 81 per cent of the power generated in South Africa comes from Escom's 23 steam-driven power stations at its 7 undertakings. The licensed areas of supply covered by these power stations total about 198,350 square miles.^{50/} Escom's extensive transmission system is at present 23,602 miles in length and its aggregate sales of electricity were over 28 billion¹⁾ kwh in 1968.

Separate accounts are kept of the expenditure and revenue of each undertaking and the tariffs of each undertaking are calculated on these figures. In terms of the Act, it is a general principle of the

1) One thousand million.

Commission that its undertakings be operated at neither a profit nor a loss and that its charges be adjusted accordingly from time to time.

Escom obtains its capital for acquiring and maintaining its undertakings mainly by loans raised from the public of South Africa, although smaller amounts have been raised overseas.

The different country-wide activities of Escom are organised into eight major area undertakings.

- (i) The largest of Escom's undertakings is the Rand and Orange Free State Undertaking, which covers the South Western Transvaal and Northern Orange Free State.
- (ii) The Natal Undertaking embraces the western half of Natal, portions of the Natal coast, and the Eastern Orange Free State.
- (iii) The Eastern Transvaal Undertaking covers the South Eastern Transvaal and is expanding northwards to cater for mining and industrial development in the area.
- (iv) The Cape Western Undertaking includes the western portion of the Cape Province and was developed inland along the main railway line to Johannesburg.
- (v) The Cape Northern Undertaking borders on the Rand and Orange Free State Undertaking and covers the area of the Cape Province to the north of the Orange River round the town of Kimberley.
- (vi) The Border Undertaking centres around East London.
- (vii) The Cape Eastern Undertaking has only recently been established and at present caters for a very small load in the area outside Port Elizabeth.
- (viii) The Orange River Undertaking, which will cover the area bordering on the Rand and Orange Free State Undertaking in the north, the Border Undertaking in the east and Cape Eastern and Western in the

south, is now being established. Once the Orange River Undertaking is established, there is little of South Africa which will not be covered by Escom's undertakings.^{50/}

In the last decade, Escom has started to interconnect the electricity undertakings, it has developed in all parts of the country to enable electricity generated at the large pithead stations on the inland coalfields to be transmitted to the more remote areas.

This interconnection is economic since the price of coal at the pithead stations is about R5.00 a ton less than at stations near the coast and, with the increasing load of the coastal areas, the saving in generating costs between the inland and coastal stations will more than compensate for the cost of the transmission system.^{51/} The stage has now been reached where it is economic to transmit power over a distance of about a thousand miles from the inland networks to the Western Cape, and a duplicate kV system capable of transmitting 400 Megawatt (MW) initially, and 700 MW at a later stage, is now under construction. This system is scheduled for completion in 1972 and the first line was commissioned in October 1969. The 400 kV system will be extended to interconnect with Natal in 1971 and with the Port Elizabeth/East London area in 1973. At this stage, all Escom's undertakings will be interconnected to form a national grid.^{51/}

Table 21 provides an indication of the development of Escom's share in the total production and sales of electricity in the Republic over the period 1928 to 1968. Sources are the various annual reports of Escom.^{52/} It should be noted that the earlier statistics relating to the Victoria Falls and Transvaal Power Company Limited have been integrated with that of Escom.

TABLE 21: ELECTRICITY SUPPLY IN THE REPUBLIC OF SOUTH AFRICA, 1928 - 1968

ESCOM AND TOTAL

YEAR	ESCOM		UNITS GENERATED (MILLION KWH)			ESCOM		SALES (MILLION KWH)			ESCOM BTU PER KWH SOLD
	CAPITAL EXPENDITURE ('000 RAND)	INSTALLED CAPACITY (MW)	ESCOM + V.P.P.	TOTAL REPUBLIC	(4) (5)	COAL BURNT ('000 TONS)	BTU CONSUMED (10 ⁹)	ESCOM + V.P.P.	TOTAL REPUBLIC	(9) (10)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1928	1,400	175.7	1,422.2	2,109.6	67.4	1,935	39,531	1,411.4	1,807.4	78.1	28,008
1929	1,575	194.7	1,516.7	2,300.1	66.0	2,086	42,449	1,560.5	2,007.6	77.7	27,202
1930	16,167	215.7	1,766.3	2,453.7	72.0	2,166	44,058	1,632.4	2,126.8	76.8	26,990
1931	16,591	215.7	1,857.4	-	-	2,237	44,873	1,689.5	N.A.	-	26,560
1932	16,823	227.7	2,028.7	-	-	2,388	47,256	1,814.2	N.A.	-	26,048
1933	17,276	247.7	2,246.4	2,946.6	76.2	2,542	49,776	1,929.0	2,462.2	78.3	25,804
1934	18,786	287.7	2,525.9	3,308.6	76.3	2,831	55,216	2,140.3	2,853.9	75.0	25,798
1935	22,981	307.7	2,848.4	3,772.5	75.5	3,152	62,139	2,414.9	3,246.2	74.4	25,732
1936	27,104	486.8	3,406.7	4,602.9	74.0	3,584	70,817	2,820.6	3,767.9	74.9	25,107
1937	30,563	519.8	3,980.6	5,336.0	74.6	3,844	76,412	3,238.5	4,361.3	74.2	23,595
1938	34,297	623.3	4,452.8	5,933.0	75.1	4,176	83,059	3,639.7	4,898.2	74.3	22,820
1939	36,645	737.7	4,740.7	6,574.3	72.1	4,409	88,184	4,095.6	5,453.4	75.1	21,531
1940	38,662	770.6	5,098.3	7,167.8	71.1	4,626	91,374	4,516.9	6,121.9	73.8	20,229
1941	40,808	771.3	5,444.9	7,592.1	71.7	4,904	97,314	4,833.5	6,504.7	74.3	20,133
1942	43,763	770.6	5,538.9	7,798.5	71.0	5,112	100,363	4,920.0	6,767.7	72.7	20,399
1943	46,574	795.5	5,404.0	7,699.8	70.2	4,978	96,867	4,795.8	6,638.4	72.2	20,198
1944	48,036	796.9	5,597.8	8,042.9	69.6	5,164	100,302	4,970.5	6,919.7	71.8	20,179
1945	49,913	862.9	5,748.7	8,328.5	69.0	5,309	105,425	5,101.1	7,142.4	71.4	20,667
1946	52,852	975.7	5,895.6	8,556.9	68.9	5,322	104,001	5,218.8	7,338.3	71.1	19,928
1947	57,650	1,033.2	6,035.9	8,787.8	68.7	6,000	106,027	5,341.7	7,493.6	71.3	19,849
1948	90,816	1,385.1	6,553.5	9,480.7	69.1	6,126	111,705	5,787.0	8,089.2	71.5	19,303
1949	100,234	1,412.0	7,075.3	10,013.3	70.7	6,366	123,474	6,109.4	8,829.0	69.2	20,210
1950	115,129	1,440.0	7,773.6	11,187.0	69.5	6,970	136,215	6,777.0	9,749.8	69.5	20,100
1951	137,283	1,520.6	8,326.6	11,895.0	70.0	7,345	143,360	7,276.0	10,473.9	69.5	19,703
1952	176,559	1,624.6	8,778.0	12,517.0	70.1	7,841	153,220	7,684.6	11,233.5	68.4	19,939
1953	218,739	1,806.1	9,442.0	13,744.0	68.7	8,150	166,718	8,214.4	11,806.3	69.6	20,296
1954	270,621	2,051.0	10,651.9	15,184.0	70.2	8,846	175,303	9,307.5	12,811.9	72.6	18,835
1955	304,342	2,377.7	12,214.5	17,172.0	71.1	9,921	194,187	10,678.3	14,309.9	74.6	18,185
1956	342,068	2,734.9	13,578.4	18,535.0	73.2	10,680	210,826	11,807.2	15,782.0	74.8	17,856
1957	377,265	2,826.7	14,388.1	19,954.0	73.4	11,266	220,846	12,702.2	17,140.0	74.1	17,386
1958	417,701	3,036.6	15,582.6	20,133.0	77.4	11,887	232,416	13,530.5	17,321.0	78.1	17,177
1959	453,130	3,289.5	16,926.5	21,165.0	80.0	12,730	245,675	14,676.1	18,132.0	80.9	16,740
1960	491,471	3,409.0	18,543.3	22,561.0	82.2	13,793	267,075	16,139.6	19,334.0	83.5	16,548
1961	529,565	3,559.0	19,575.4	24,556.0	79.7	14,245	280,034	17,035.5	20,968.0	81.2	16,438
1962	581,579	3,759.0	20,805.5	26,105.0	79.7	15,383	293,932	18,205.0	22,066.0	82.5	16,146
1963	637,076	4,176.0	22,312.4	28,828.0	80.2	16,227	310,054	19,500.0	23,706.0	82.3	15,900
1964	679,193	4,499.6	24,355.3	30,422.0	80.1	17,256	327,195	21,247.5	25,257.0	84.1	15,399
1965	741,109	4,624.8	26,440.4	32,772.0	80.7	18,438	353,552	23,143.3	N/A		15,277
1966	840,782	4,806.4	27,395.5	34,758.0	78.8	18,720	356,658	24,554.3	N/A		14,525
1967	950,863	5,845.4	30,421.7	37,869.0	80.3	20,181	389,445	26,657.1	N/A		14,609
1968	1,114,390	6,344.7	33,061.2	40,948.0	80.7	21,091.5	410,462	28,885.0	N/A		14,210

From Table 21, it is evident that the total consumption of electricity in the Republic of South Africa has grown thirteen-fold from 1.8 billion kwh in 1928 to over 25 billion kwh in 1964, or at an average annual increase of 7.5 per cent. An average annual increase of this magnitude has the implication of doubling total consumption every ten years.

The sixth column of Table 21 shows how Escom's share of the total national production grew to almost 81 per cent in 1968. The remainder is mainly contributed by the large municipal power stations at Johannesburg, Pretoria, Cape Town, Port Elizabeth and Bloemfontein. Plans are in hand for Escom to supply all future load growth of these municipalities, so that in a few years time Escom will supply about 97 per cent of the South African load.^{51/}

Table 22 illustrates the changing demand pattern of the total national consumption of electricity. Mining's contribution to the total declined from 43.7 per cent in 1956-57 to 38.6 per cent in 1963-64, whereas the market share for industry increased from 31.0 per cent to 36.8 per cent over the same period. It does, however, underline the continued importance of the mining sector to the electricity industry as well as to the entire national economy.

In 1962, South Africa ranked 12th in the world in terms of per capita consumption of electricity,^{19/} whereas in 1966 South Africa's position as regards total national production was 18th amongst the countries of the world.^{53/} South Africa further contributed 54 per cent of all electricity generated on the continent of Africa in 1968.^{54/}

TABLE 22: TOTAL CONSUMPTION OF ELECTRICITY BY MAJOR SECTOR IN THE REPUBLIC OF SOUTH AFRICA,
1956-57 TO 1963-64 (MILLION KWH)

YEAR	MINING	INDUSTRIAL & COMMERCIAL	TRACTION		S.A.R. NON-TRACTION	DOMESTIC	STREET LIGHTING	OTHER PURPOSES	TOTAL NUMBER OF UNITS SOLD
			S.A.R. & H.	TROLLEY BUSES AND TRAMS					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1956-57	7,493	5,306	771	54	131	2,724	131	530	17,140
1957-58	7,510	5,489	776	52	134	2,784	131	445	17,321
1958-59	7,765	5,836	810	49	116	3,078	146	332	18,132
1959-60	8,237	6,153	907	55	189	3,361	197	235	19,334
1960-61	8,796	6,830	1,033	44	214	3,538	192	321	20,968
1961-62	9,121	7,547	1,181	43	223	3,469	199	283	22,066
1962-63	9,524	8,444	1,296	41	249	3,724	222	206	23,706
1963-64	9,758	9,303	1,389	31	277	4,221	232	46	25,257
	8.6%	4.1%	5.5	1.2	1.1	16.7	.9	1.8	99.9

2.3.1.3 Factors affecting the location of future thermal power plants

The siting of a power station depends upon its size and type; the availability, location and cost of exploiting the source of primary energy; the availability and cost of providing the water required for cooling purposes; the cost of transmission line to the load centre; and the cost of providing road and rail access. The site which gives the lowest overall cost of electrical energy delivered to the load centre is obviously the best one to select.

Because coal is found abundantly in the Republic and hydro-electric potential is limited, large steam electric power stations have so far been built almost without exception. However, the implementation of the Orange River Project, when a number of hydro-electric power stations will be built in the near future, will be a deviation from this practice.

The vast gold mine and industrial complex in the Southern Transvaal and Northern Orange Free State, and the industrial and agricultural area on the Natal coast, have in the past required increasingly large amounts of power, and will continue to do so for a long time to come; particularly if all generation in the Republic is progressively integrated.

The large coal reserves in the Transvaal and Natal, and, up to the present, adequate supplies of cooling water, have made the construction of large pithead power stations possible in these two provinces.

The installed capacity of the power stations built by Escom has increased over the years, from 25-40 MW in 1947 (e.g. the Colenso, Congella and Vaal Stations), to 120-424 MW in 1956 (e.g. Salt River, Taaibos, Vierfontein and Klip) to 480-1600 MW in 1966 (Ingagane, Highveld, Komati and Camden).¹⁴⁷ The Grootvlei station, nearing completion at Balfour, has a capacity of 1000 MW, whereas the latest plant, the Hendrina power station, will have an installed capacity of 2000 MW.

The latter station will be amongst the biggest coal-fired stations in the world. As was mentioned before, investigations have shown that, under present conditions, the best economical solution is to supply power from large pithead power stations for which the supply of coal can be independent of rail transport costs. A further advantage of a pithead station is that it can be large in overall capacity, since coal handling is reduced to a minimum.

It is, however, thought that a station of 2000 MW is the limit on a truly pithead basis. These large-capacity power stations make the supply of coal on a true pithead basis impracticable, as the coal reserves for these cover a big area. For a 2000 MW plant, coal reserves of over 250 million tons are necessary and must cover a large area.⁵⁵⁷ Indications are that, on the present exploited deposits, Natal cannot support a power station having a larger installed capacity than 1000 MW.⁵⁰⁷ Thus, if 2000 MW capacity is required and has to be sited in Natal, two suitable sites would have to be found instead of one. However, if, in future, nuclear power stations were to be selected, then large power stations become feasible.

Apart from the lower operating and maintenance costs derived from having large generated capacity concentrated in one station, an important factor is the overall efficiency of the station, as this is a measure of the effective use that is made of the thermal resources. While it would appear that maximum efficiency should be aimed at, this is affected to a great degree by the coal costs. Where coal is cheap, it does not pay to install very expensive designs in order to gain a few per cent in thermal efficiency.⁵⁵⁷ Nevertheless, from the 12th column of Table 21 it is clear the overall thermal efficiency of Escom has increased from 28,008 Btu per kwh sold in 1928 to 14,210 Btu/kwh in 1968, or at an average annual increase of 1.7 per cent. It is to be expected that the

overall thermal efficiency of Escom will further continue to improve, at least until all the giant pithead stations planned for the Eastern Transvaal coal fields are in operation. Current indications are that aggregate capacity for the area will be 7,350 MW by 1975.¹⁴⁷

The question of the adequate supply of cooling water is a very important one, and may in time become a more limiting factor than adequate coal supply. Hence, the inadequate coal reserves in Natal may require that future coal-fired power stations for that undertaking will have to be built on the Transvaal coal fields, where difficulties will be encountered in finding sufficient cooling water.⁵⁰⁷

It is common knowledge that water is a relatively scarce article in South Africa. There are only a few perennial rivers and natural lakes in the Republic, and rainfall is confined to less than six months of the year over 85 per cent of the total area. Furthermore, the run-off is not proportional to the mean rainfall because of the high evaporation rate and seasonal parching.⁵⁵⁷

Since the stream flows, which follow the rainfall pattern, are seasonal and irregular, large dams and storage reservoirs must be built to obtain appreciable quantities of water at inland centres. Unfortunately, suitable storage sites with adequate catchment areas to serve them are rare. They are comparatively flat so that the dams are shallow and lose much water by evaporation. Owing to the strong flow of the rivers during the rainy season, they are prone to carry large amounts of silt, which reduces the effective capacity of the dams. For these reasons, it is very essential that the exploitation of the whole of any river basin should be carefully planned. This is the task of the Department of Water Affairs, which must provide Escom with the water it needs. In most cases, dams must be multi-purpose, which invariably is the case where they

serve Escom, as they are built much larger than is needed for purely supplying Escom's demands.

In this respect, it may be said that the Commission is serving a two-fold purpose in opening up new territory for industrial and agricultural development. It not only provides the cheap power, but often also helps towards making a cheap supply of water available.^{55/}

The average water consumption of Escom's thermal power stations using cooling towers is about one gallon per kwh sent out.^{55/} About 75 per cent of this water is evaporated, and the rest lost as cooling tower blow-down, which is also used for de-ashing, boiler blow-down and domestic and garden use in the housing schemes built around the power stations.^{55/}

An investigation recently carried out by the Department of Mechanical Engineering of Escom on the potential of cooling water for thermal power stations yielded important findings.^{44/} It established a mean annual run-off of 4.32×10^6 - 4.63×10^6 morgen-feet of water for all the rivers crossing the Eastern Transvaal border (i.e. the Limpopo, Great Olifants, Letaba and Shingwedzi, Komati, Usutu and Pongola) in the vicinity of the low-cost coalfields. Within the framework of the policy of the Department of Water Affairs, it can be expected that a maximum of 2.0 per cent to 2.6 per cent of this total, or 112,140 morgen-feet a year, will be made available for power station cooling water; the Vaal River basin being considered over-taxed already. This means that Escom will, in the near future, be limited, as far as cooling water in its Eastern Transvaal Undertaking is concerned, to a maximum of 307 morgen-feet, or 176×10^6 gallons per day. As was already indicated, Escom will have a total installed capacity of 7,350 MW in the area by 1975, with a resultant demand of 132×10^6 gallons of water per day for use in

wet-cooling towers.

One possible solution to the problem could be the use of so-called dry-cooling systems, once they are proved in service.^{50/55/} A power station with these cooling towers only requires about 10 per cent of the water consumed by a station with conventional cooling towers, a fact which could leave room for an additional 12,600 MW of generating power in the Eastern Transvaal area.^{14/} The cost of the dry-cooling tower system is, of course, much higher. The capital cost involved, which when compared with a wet-cooled system, may be as much as 12 per cent higher.^{55/} The last of the economic comparisons between the two systems, which Escom carries out periodically, has indicated that, for a 200 MW set, the extra annual cost, at 80 per cent load factor, for dry-cooling would be of the order of R172,000, which in generation cost would represent an increase of between 5 and 6 per cent.^{55/}

Furthermore, when water resources in the Transvaal become inadequate for power generation, water could be pumped from the Tugela in Natal, but the desirability of this is still open to question. The most reasonable approach, when inland water becomes scarce and must be saved for industrial and domestic purposes, is to build the large power stations on the coast, where sea water can be used for cooling purposes. In such an event, it is probable that nuclear power will become competitive with coal power, and that these coastal power stations will be nuclear.^{50/}

It is, therefore, quite possible to envisage a series of coastal nuclear power plants, during the latter half of the seventies, which will feed energy centripetally to a network in which the pattern of flow had initially been centrifugal.^{55/56/} The realization of such a reversed system of power supply could, however, also result in progressively more expensive electricity.^{14/}

2.3.1.4 The average prices of South African electricity

It has not been possible to obtain the average prices of electricity sold by all producers in South Africa. In Table 23, however, the relevant information, by sector, is provided in respect of Escom sales over the period 1949 to 1968. The data were kindly supplied by Escom in a private communication. The fact that it was only possible to obtain information from Escom should not give rise to concern, as it was seen in Table 21 that Escom held by far the greatest market share over the period. The monetary values are again expressed in current prices.

From column (6) of Table 23 it is clear that the average prices of electricity, for the country as a whole, roughly doubled over the last two decades, or increased on the average annually by 4.0 per cent.

2.3.2 Hydro-electricity

Owing to lack of strong flowing rivers and periodic droughts, hydro-electricity has so far contributed very little to the overall energy supply in South Africa. Some small plants have in the past been in operation at Sabie, Umtata, Parys and Ceres but production at these locations has been limited and interrupted through lack of water.

2.3.2.1 The Orange River Development Project

The Orange River Project, as set out in a White Paper⁵⁷ presented to Parliament in 1962, made provision for the generation of hydro-electricity at a number of inland sites. The initial combined capacity of all stations was only about 40 MW but after further study⁵⁸ it was decided to increase the capacity of the dams with a resultant further increase in electricity generating capacity of about 100 MW. The maximum capacity, which will only be achieved during the 4th stage of the

TABLE 23: AVERAGE PRICES OF ELECTRICITY SOLD IN THE REPUBLIC OF SOUTH AFRICA

BY ESCOM, 1949 TO 1968 (CENTS PER KWH SOLD)

YEAR	TRACTION	BULK	MINING	INDUSTRIAL	DOMESTIC & STREET LIGHTING	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)
1949	.3421	.3375	.2028	.2806	1.0937	.2611
1950	.3557	.3535	.2069	.2860	1.0870	.2701
1951	.3574	.3701	.2274	.3030	1.0321	.2877
1952	.3811	.3807	.2460	.3128	1.0630	.3055
1953	.4618	.4199	.2829	.3604	1.2083	.3488
1954	.5318	.4638	.2992	.3881	1.3247	.3763
1955	.6195	.5225	.3262	.3991	1.3485	.4099
1956	.6349	.5448	.3344	.3992	1.3625	.4207
1957	.6448	.5694	.3527	.4150	1.3847	.4409
1958	.6556	.5861	.3789	.4407	1.4294	.4663
1959	.6671	.6049	.3963	.4681	1.4411	.4863
1960	.6643	.6009	.4144	.4833	1.4492	.4987
1961	.6727	.6127	.4216	.4943	1.4843	.5096
1962	.7398	.6094	.4174	.4873	1.4784	.5109
1963	.7284	.6044	.4192	.4878	1.4756	.5125
1964	.6910	.5910	.4121	.4901	1.4426	.5072
1965	.6963	.5912	.4057	.4819	1.3983	.5051
1966	.7172	.5969	.4182	.5108	1.3851	.5218
1967	.7524	.6068	.4444	.5368	1.3931	.5467
1968	.7553	.6034	.4493	.5513	1.3910	.5549

Project, will be about 229 MW. It is, therefore, clear that the Orange River Project, important as it is from the point of view of national water supply, will barely make a significant contribution to the future supply of power in South Africa.

2.3.2.2 The Cabora-Bassa hydro-electric scheme in Mocambique

Work has already begun on the building of a dam which will harness the Zambesi at Cabora Bassa - a site in the Kebrabasa Gorge in Northern Mocambique - 150 miles downstream from the Rhodesian border.^{59/} The Cabora Bassa scheme in its entirety makes provision for four dams - Cabora Bassa itself and three dams lower down the Zambesi at Mepanda, Uncua, Boroca and Lupata. Together, they will eventually generate 50,000 million kwh of power a year, with the main dam providing 18,000 million kwh a year. Neither the Kariba Dam, further up the Zambesi, nor the Aswan Dam on the Nile, which produce 9,000 million kwh and 10,000 million kwh, respectively, have the capacity of the Portuguese project.^{60/}

The ultimate capacity of the scheme, initiated jointly by the South African and Portuguese Governments, has been estimated at 4,000 MW.^{61/} South Africa has agreed to buy the output of 1,000 MW of Cabora Bassa by 1974, rising to 1,700 MW by 1980. In doing so, South Africa abandoned its traditional policy of relying on national energy resources for power supply, and accepted the principle that 8 per cent of the country's electricity will in future come from Cabora Bassa.

Power will eventually flow over 865 miles of transmission lines to a point near Pretoria where it will be fed into Escom's national grid. Despite high transmission costs, this power will be delivered in the Transvaal for much less than the cost of generating it in the Republic and, in doing so, a substantial contribution to the conservation of the scarce water supplies in the country is made.

2.3.2.3 The Oxbow Scheme

The Oxbow Dam Scheme to supply water and electricity to South Africa from the Maluti Mountains of Lesotho was agreed by the two governments, after a preliminary investigation, in February 1968. The cost of the Oxbow Dam and its hydro stations (the first stage of the scheme) was put at R30 million, and Lesotho approached the World Bank for finance. The Bank wanted a further feasibility study, and made an allocation of R1.2 million for this purpose. Consulting engineers have since been appointed and investigations are still being carried out.

The project initially envisaged the generation of 353 million kwh per annum in a cascade of hydro stations discharging ultimately into the Caledon river, while, at the same time, making available 40 million gallons a day (mgd) for gravitation to the Orange Free State.⁵⁶⁷

It would seem that direct supply of water to the Witwatersrand complex would be a preferable scheme. Studies have revealed that it would be feasible to divert, from a series of dams in the upper tributaries of the Orange, a steady supply in the order of 250 mgd northwards into the Vaal catchment, without significantly affecting the potentialities of the Orange River Project.⁵⁶⁷ About 500 million kwh of electricity could be extracted from the flow, in its descent from the mountains of Lesotho, before release for its onward journey to the north.

As was indicated, the Project is still under investigation, and the final report of the consulting engineers is only expected by the beginning of 1971.

2.3.3 Nuclear electricity

In view of the fact that coal is at present produced at a cost of less than R1.50 per ton at the larger pithead stations (which is almost

R5.00 per ton less than the delivered cost of coal in the coastal areas), it is not surprising to find that power can be generated in the Transvaal and transmitted by high-tension lines to the Cape, at a cost lower than it can be produced by a coal-burning station at Cape Town.

Thermal power at the coast is relatively expensive. This fact, coupled with the possibility of an inland water shortage looming in the future and the fact that the 400 kV grid is to be greatly extended, makes nuclear power along the coast a strong contender in the next ten years or so. Furthermore, there are coastal areas where the supply of fresh water for industrial and urban use will be a problem, and where a dual-purpose desalination and electric power generating station, based on nuclear fuel, would be a decided asset.

It has been indicated, for instance, that a 2000 MW power station, such as Escom is building at present, consumes about 20,000 tons of coal a day, or twenty train loads, whereas a well designed nuclear station of the same capacity would use less than a ton of uranium a day.⁶⁷

The Government has already asked the Atomic Energy Board, together with Escom, the S.A. Railways Administration, and the Department of Water Affairs, to investigate the question of the installation of nuclear power stations along the coast, taking such factors as size of stations, suitable areas, siting requirements, time of installation etc. into account.⁵⁰⁷ A number of reports have also seen the light in this regard. The practical and economic aspects of the generation of power have been considered, but, apart from these, other factors such as the effect of the introduction of nuclear power in the country on the uranium industry, as well as on the general industrial development, has been analysed. It is also known that the Government has already authorised the introduction of nuclear power in South Africa, and that work is now in progress at Melkbosstrand, near Cape Town, on the erection of South Africa's first nuclear power plant.

The conclusion is therefore drawn that, although South Africa has vast resources of coal, for very good reasons, outlined previously, the introduction of nuclear power to an ever-increasing degree becomes inevitable as time progresses. This being so, it appears relevant to briefly review developments in the field of nuclear power generation in the world in general, and South Africa in particular.

2.3.3.1 Brief outline of international developments

(i) United States of America:

By 1945, the U.S.A., in the course of its development of the atomic bomb, had built up a large team of scientists and engineers who had gained considerable knowledge, and developed many new techniques in the field of atomic energy. Perhaps even more important was the existence of large plants for the enrichment of uranium¹⁾, for the extraction of plutonium, and for the production of heavy water. Although all these developments arose from the military programme, many of them were applicable to the peaceful uses of atomic energy; the diffusion plants in particular have profoundly influenced the subsequent development of nuclear power throughout the world.

After the war, the U.S.A. was in the fortunate position of having adequate supplies of enriched uranium, a large reserve of skilled personnel, many specialised facilities, and considerable funds available for nuclear development. It was, therefore, able to investigate almost all the various promising types of power reactors, but, as the country possessed abundant sources of cheap

1) Increasing the ^{235}U - content of natural uranium.

fossil fuels and hydropower, there was no urgency for the introduction of commercial nuclear power stations. A large number of different prototype reactors were built, and the more promising of these types were then constructed in larger capacities, so that economic and technical information applicable to a full-sized power station could be obtained.

From the experience gained with these "power demonstration reactors", the Boiling Water Reactor (BWR) and Pressurised Water Reactor (PWR) types gradually emerged as the most economical.³²⁷ Spectacular reductions in the generation costs of these two types were achieved, as a result of development and design work undertaken by the United States Atomic Energy Commission and private companies, and by the construction of units of larger capacities.

By 1964, several studies showed that BWR and PWR stations would be competitive with fossil-fuelled stations in many regions of the U.S.A., and evaluations during 1965 and 1966 showed that these power reactors had, by then, become economical even in regions where low-cost fossil fuels were available.³²⁷

These findings resulted in a dramatic increase in orders for large commercial power stations of these two types, and, in the U.S.A. alone, 24 nuclear plants, totalling 20,000 electrical megawatts, were ordered during 1966, and orders for a further 30 power reactors, with a combined generating capacity of 25,000 electrical megawatts, were placed during 1967³²⁷. Many other countries have shown keen interest in these types of reactor, and twenty three were in operation, under construction, or on order, in Western Europe and Japan by the end of 1967.

Most experts deem it necessary to introduce commercial fast breeder reactors on a large scale by the mid-eighties; in order to reduce future uranium demands through their very efficient utilization

of uranium and thorium resources. Consequently, there has recently been great emphasis placed on the rapid development of fast breeder¹⁾ systems in the U.S.A.

Although BWR's and PWR's are generally expected to retain their dominant position in the market until fast breeders are commercially available, other advanced types are being actively developed, notably the high temperature gas cooled reactor and the molten salt thermal breeder system.³²⁷

(ii) United Kingdom:

The situation in Britain at the end of the war was rather different. Although nuclear experience had been obtained, and facilities had been built during the war, enriched uranium was not available locally. It was, therefore, decided to develop a natural uranium reactor system, and the "Magnox" gas-cooled, graphite-moderated type was chosen, because it presented the least technological problems.

Predictions of a dire shortage of coal, coupled with some rather optimistic estimates of the costs of nuclear power, led to plans for the construction of a large number of commercial nuclear power stations. Because the cost of nuclear power did not decrease as rapidly as had been expected, and the generation costs of fossil-fuelled stations became lower than originally predicted, it was later decided to

1) A new type of reactor which produces additional fuel while in operation. In cases where more fuel is produced than consumed they are called breeder reactors.

reduce the size of the nuclear power programme. Britain still, however, has the largest installed nuclear generating capacity in the world, and, to date, has generated more electricity by nuclear means than the rest of the world.³²⁷

When appreciable reductions in cost of power from Magnox Stations did not appear possible, attention was directed to enriched uranium reactor systems, since enriched fuel was soon to be available from the British diffusion plant. The result was the Advanced Gas Cooled Reactor (AGR), which utilized much of the technology of the Magnox reactors, but had lower capital and fuel costs.

The success of the prototype AGR led to the decision that no more Magnox Stations would be constructed, so that the AGR will probably be used for the next generation of stations in the United Kingdom, although a type of heavy water reactor (called the Steam Generating Heavy Water Reactor or SGHWR), developed by the United Kingdom Atomic Energy Authority, may be competitive with the AGR.³²⁷

A comparison, made by the Central Electricity Generating Board, between the BWR and AGR showed that the AGR had slightly lower generation costs, under the ground rules selected, but which of these two types would be the most economical in other countries could well depend on local financial and industrial conditions.

The United Kingdom Atomic Energy Authority has also devoted considerable effort to the development of fast breeder reactors. A 250 MW unit (called the Prototype Fast Reactor or PFR) is at present under construction, which probably places the United Kingdom in the forefront of world fast reactor development at the present time.

(iii) Canada:

Much of the early work in Canada was devoted to heavy water reactors, and the Canadians decided to continue development of this type, as it looked promising and was operable on natural uranium.

By concentrating their limited manpower and resources on the heavy water moderated and cooled reactor, they have brought it to a commercial stage of development, where it is probably the most economic and efficient type of natural uranium reactor. It has been predicted that improved and larger versions of this reactor will be competitive with the enriched types, such as AGR, PWR and BWR.³²⁷

(iv) France:

France is the only other non-Communist country which has a nuclear research and development programme comparable with those of the U.S.A., the United Kingdom and Canada. Although a late starter, France has made good progress in many branches of nuclear technology, including power reactors and enrichment and reprocessing plants.

The French power reactor programme has been very similar to that in Britain. The early developments were almost entirely concentrated on the natural uranium fuelled, graphite moderated, gas cooled reactors, because the technology was well known and enriched uranium was not necessary. In spite of the high capital cost involved, France is continuing to build this type, presumably because enriched uranium from the French diffusion plant is not yet available in large quantities for non-military purposes.³²⁷ A further similarity with the United Kingdom programme is the active development of heavy water and fast breeder reactors.

(v) Other overseas countries:

The U.S.S.R. has a large atomic energy programme, which includes the development of several types of reactors (e.g. pressurised water and fast breeder systems), but lack of cost data makes these projects of rather academic interest outside the Communist countries.

Germany has embarked on a large nuclear power programme, based at present on the pressurised and boiling water reactors. Increased emphasis is, however, also being given to development of advanced systems, in particular, fast breeders.

Sweden is also developing an original heavy water power reactor system, but it has not evoked much interest outside the country, and even Swedish utilities have shown greater interest in the American types of reactor.

A few other countries (such as Czechoslovakia and Switzerland) are working on novel power reactor types, independently, in collaboration with other countries, or through international organisations such as Euratom. Co-operative reactor projects, such as Dragon and Essor, have reached an advanced stage of development, but there has so far been a noticeable absence of interest in building large power stations of these types.

Most other countries with nuclear power programmes, such as Belgium, India, Italy, Japan, Netherlands, Pakistan and Spain, have chosen power reactors of types that have been developed elsewhere, e.g. in the U.S.A., United Kingdom or Canada.

(vi) South Africa:

The Republic was brought rather suddenly into the atomic energy field during the last war through the discovery of large reserves of uranium within its borders. The Atomic Energy Board was formed in 1948, but remained essentially an administrative body until 1959.³²⁷

Interest in atomic energy developments during the late forties and early fifties arose mainly from the uranium industry's desire to strengthen its position in world markets, which were becoming progressively more competitive.

There was no urgent need at the time to consider constructing nuclear power stations in South Africa, in view of the country's abundant reserves of very cheap coal. On the other hand, the availability of low cost uranium, and the rapid progress made in atomic energy overseas during the 1950's indicated that nuclear power might be economical in South Africa in the not too distant future, and that the formulation of a national atomic energy programme was becoming highly desirable.

In 1956, a Commission^{31/} was appointed to enquire into the application of nuclear power in South Africa. The findings of the Commission, which were published in 1961, were rather inconclusive regarding the relative economics of nuclear and conventional power generation. This was due mainly to the unavailability of reliable cost data on power reactors, and to the lack of expert knowledge on nuclear energy in the country at that time. The Commission recommended that the situation be reviewed again when more information became available.

In 1959, the Atomic Energy Board set out its research and development programme, which provided, inter alia, for the training of scientists and engineers in nuclear technology, for technical assistance to strengthen the uranium industry's position in world markets, for the development of nuclear power, and for the increased participation of industry in this development.

In 1961, the Atomic Energy Board decided to embark on the development of a novel power reactor concept, called PELINDUNA.^{32/} The reasons for this decision were that PELINDUNA was expected to have low generation costs, to be operable on natural uranium, and to be suitable for local manufacture. Good progress was made on this project, but, as development proceeded, it became clear that this type of reactor would only be economical, in the capacities of interest, if enriched

fuel were used.³²⁷ Because of the uncertainties in ensuring a supply of enriched uranium, it was decided in August, 1967, to discontinue work on PELINDUNA.³²⁷

The experience gained by the scientists and engineers who worked on this project will, nevertheless, be of considerable value when the first power reactors are introduced in South Africa. PELINDUNA also involved much of the technology of fast breeder reactors, so that most of the knowledge gained in its development will be applicable to fast breeder power stations, which are expected to come into service in the 1980's.³²⁷

During May 1968, a report on the investigation into the possible introduction of nuclear power in the Republic of South Africa³²⁷ was published by the Atomic Energy Board. This was the first serious attempt to evaluate nuclear power in South Africa since the previously mentioned report of the Commission in 1961. In the intervening 6 years, a considerable amount of data had become available as a result of reactor experience overseas, and it was felt at the time that there was then sufficient reliable information to make a meaningful evaluation of the possible introduction of nuclear power in the Republic.

In this investigation, use was made of the best nuclear power information available, which was obtained with the assistance of overseas experts in atomic energy. The report endeavoured to provide answers to the most important questions relating to the introduction of nuclear power: the type of nuclear reactors to be considered; the capacities of the first nuclear stations; the regions where they should be installed and the dates on which they should come into operation; the probable effects on the national economy; and the use of nuclear power for desalination of sea-water.

The report states that there are, however, other long term aspects which should be assessed in the near future; for example, the expected

further growth of nuclear power in the future, and the availability of plutonium from thermal nuclear stations for the initial fuelling of fast breeder reactors which may well come into service after 1985. These aspects have not been fully covered in the investigation, because such evaluations are exceedingly complex and time consuming, and it was considered essential that the completion of the afore-mentioned report should not be delayed for the sake of these long-term implications. It is the intention that a supplementary report, to be issued in the near future, will provide this additional information, which is required for the long-term planning of a nuclear power programme for South Africa.^{32/}

2.3.3.2 Significant findings and conclusions of recent investigations into the introduction of nuclear power in South Africa

The most recent official investigation into the problem of assessing when nuclear power would become competitive with conventional power in South Africa, as already mentioned, is the report^{32/} published in 1968 by the Atomic Energy Board. In discussing its conclusions, the report states:

"Consideration should only be given to those types of power reactors which can be regarded as having adequately proven economics and operating characteristics at the time of placing the order.

There should be absolute assurance that nuclear fuel will be available over the entire lifetime of any commercial nuclear power station in South Africa. Because the continued and assured supply of ENRICHED uranium for a power reactor in this country is at present subject to grave doubts¹⁾,

1) In the Western world, enriched uranium is produced by America and France only, because of the high cost involved. The total cost of the three American plants, for instance, is estimated at R1600 million, and R700 million for the much smaller French plant. Estimates of the cost of a planned joint plant, involving Britain, Holland and West Germany, range from R340 - 625 million.

only those types of power reactors capable of operating on a feed of natural uranium can be considered at the present time.

Boiling water and pressurised water reactors (BWR and PWR) and advanced gas-cooled reactor (AGR) types cannot therefore be considered at present as they cannot be operated on natural uranium. Because of the possibility that one of these enriched fuel reactor systems may be more economical than the natural uranium types, enriched reactors should be considered, if, at the time of placing the order, the uncertainties regarding an assured supply of enriched fuel have been resolved."

It is of course now generally known, as disclosed by the Prime Minister in July 1970, that South African scientists have developed a process of uranium enrichment which is commercially competitive with processes currently in use internationally. This removes the uncertainty regarding the availability of enriched fuel for the future introduction of nuclear power in South Africa.

Despite these developments, it is, nevertheless, significant to consider some of the conclusions reached in the above-mentioned report:

(i) Comparative economics of nuclear power

Based on estimated costs of CANDU¹⁾ reactors in the 200 MW to 500 MW range, and on the predicted future conditions in the South African electricity supply systems, a detailed evaluation of nuclear power shows that:-

(a) A CANDU-type nuclear power station of between 200 MW and 350 MW capacity would be economical in its first year of

1) The Canadian (CANDU) heavy water moderated and cooled type reactor has been selected as a basis for this study.

operation in the Western Cape, if it were placed in full commercial service between 1978 and 1980.

(b) There is no economic incentive to incorporate a nuclear power station in the Natal system in the near future, but the situation should be reviewed again by 1975.

(c) Nuclear power is so far from being competitive in the Rand and O.F.S. and Eastern Transvaal Undertakings that it is not at present possible to predict when it is likely to be economically viable in this region.

(d) Nuclear power is unlikely to be economical in any region of the Republic before the electrical demands have increased sufficiently to allow the installation of a reactor of reasonable capacity, i.e. about 200 MW or more.

(ii) Effects on natural resources

If "dry cooling" proves to be successful, as is expected, then the water supplies in the Eastern Transvaal should be adequate for power generation purposes until beyond the end of this century. It would, therefore, appear that the conservation of inland water supplies cannot be used as a justification for the introduction of nuclear power stations at the coast during the next 30 years.

South Africa's coal reserves, although large, are by no means inexhaustible when viewed against the increasing rate of demand. Nuclear power will provide an important alternative energy source; by gradually reducing the rate of increase in coal demands for electricity generation, it will help to conserve the country's reserves and thereby allow more coal to be allocated to the production of liquid fuels and chemicals. Because the proportion of nuclear generating capacity will initially be small,

and will only increase gradually, the increasing demand for coal for electricity production will continue for many years. Thus the introduction of nuclear power is not expected to create problems for South Africa's coal industry.

(iii) Desalination

There does not appear to be any region in South Africa where nuclear desalination plants can now compete in price with water from natural sources. On costs predicted at present for desalination, it is also likely that desalinated water would not be competitive for many years. Technological improvements, resulting in sizeable reductions in the costs of desalination, may, however, bring forward the date when nuclear desalting becomes economical.

As there is no urgency for the construction of desalination plants, it is recommended that the situation be reviewed again in the future when more reliable data on desalination are available.

It, therefore, appears possible that South Africa will be able to progress directly to the stage of using enriched nuclear fuels for power generation without first introducing reactors fuelled by natural uranium. South Africa further possesses about a third of the western world's known reserves of low-cost uranium (amounting to 600,000 tons), recoverable at \$8 per lb. or less.^{6/} The local availability of sufficient quantities of enriched fuel will, therefore, no longer place a constraint on the selection of the most economical reactor types. Cost studies undertaken by Human^{14/} indicated that reactor types using enriched uranium fuels will, in the long run, be more economical, yielding the lowest kwh-cost. Based on the economics of reactors using enriched fuel, Human projects installed nuclear capacities of 580 MW by 1980, 1393 MW by 1985, 4057 MW by 1990, 13133 MW by 1995 and 26257 by 2000.^{14/} The

findings and conclusions of the report discussed above must, therefore, be seen as bordering on the conservative side; a new assessment appears desirable and it may well be found that break-even points are reached much earlier than previously contemplated.

2.4 The oil industry in South Africa

2.4.1 Introduction

The international oil industry - the world's biggest industry - is an industry fraught with paradox. That it is difficult to conceive any other industry possessing more wealth and, at the same time, suffering from more problems, is illustrated by the following:

- Of the world's estimated ultimate reserves of crude oil, 525,000 million tons, hidden under the crust of the earth, only 10 per cent have been proved and they, in addition to providing the raw material for this important industry, are instrumental in world politics.
- Three-fourths of the proven oil is in countries of North Africa and the Middle East, which need foreign capital, expertise and enterprise, and resent the fact.
- Seven international, but Anglo-Saxon, companies (Esso, BP, Shell, Gulf, Texaco, Socal and Mobil) virtually monopolise the industry and are tolerated - though unloved - by the Germans, French, Italians and Japanese (among others).
- At a time when the producing countries are demanding higher royalties and pressing for partnership agreements, oil is discovered in other parts of the world (such as Alaska and the North Sea), thus reducing the dependence of the major markets on the more volatile producing areas.

- At the same time, eager upstart companies are beginning to challenge the seven major oil companies, undercutting them in the marketplace, and concluding new, revolutionary types of agreements with the producers.
- To complicate matters, add the mounting Soviet interest and influence in the Middle East, and the uncertainties of the Arab-Israeli conflict.

So, although the world, presently at least, has all the oil it can use, the search for new sources of supply, preferably nearer to the main markets and certainly less fraught with political risk, is as frenetic as ever. And while the producing countries would like to reduce the seven major international companies to the role of mere contractors, they still rely on them to regulate world oil prices and give stability to the international oil scene.

The key fact working for sanity, and the status quo, is that the crude oil taken from the ground (at comparatively little cost) is worthless until it is transported, processed and distributed in the markets that will tax it, and pay for it, and turn it into wealth. The strength of the international oil companies really lies in the fact that they are technically and financially equipped to ensure the flow of oil from the producing wells to the final consumer. The extent to which they dominate oil marketing is illustrated by the fact that their aggregate sales reached \$46,000 million in 1968.⁶²⁷

Taking their cue in part from the solidarity displayed by the companies, and angered by the international companies' action in unilaterally reducing oil prices in the Persian Gulf area, the producing countries themselves formed a kind of cartel in 1960.

The OPEC (Organisation of Petroleum Exporting Countries) is based in Vienna, and its 10 member nations account for about 72 per cent of world oil reserves, 45 per cent of production, and 86 per cent of oil exports. Their share of refining capacity is 8 per cent, which illustrates afresh where the relative strengths and weaknesses lie in the oil mosaic.

Organisation on the part of the producing countries did result in stronger bargaining power vis-à-vis the major companies, and agreements reached over the last number of years are characterised by a greater degree of participation in the industry by producing countries. For example, in 1969, Iran concluded a service agreement with AREPI, a consortium including French, Italian, Spanish, Belgian and Austrian interests.⁶²⁷ The beneficiary takes on himself the entire risk of exploratory drilling, which is not unusual; but, if he finds oil, he does not own it. Instead, his exploration costs are refunded and he is given the opportunity of buying some of the oil, at a special price, from a national company appointed by the host government.

Clearly, this arrangement suits the producing country, which effectively retains control of its oil. It is also sufficiently profitable to attract foreign companies outside the circle of the big seven. The fact is that a new and unaccustomed fluidity characterises the world oil industry; and it does not only reflect the militancy of the producing countries. Some of the other developments affecting the situation include:⁶²⁷

- (i) The shift of the oil-field centre of gravity away from the Middle East toward Africa:

The Middle East still possesses 58.5 per cent of the world's oil resources, as ascertained at the end of 1968.

But, whereas African oil practically did not exist ten years ago, in 1968 it accounted for 9.4 per cent of all proven reserves.

In the first quarter of 1969, Libya produced 400,000 tons a day (compared with Iran's 432,000 tons) and, with less than half of Kuwait's reserves, has outpaced its production.

Nigeria produced 70,000 tons a day of oil in the first quarter of 1969 - despite the civil war - and should reach its target of 100 million tons by 1971. It will then be among the seven or eight major producers in the world.

The development of North African supplies was speeded by the Arab-Israeli war of June 1967. When the Suez canal was closed, the international oil companies showed their flexibility by manipulating world supplies, keeping oil flowing, and placing huge orders for tankers.

Just the same, Italy, for example, now takes only 33 per cent of her oil from the Persian Gulf, compared with 62 per cent before the June war, due to the long voyage round the Cape and the proximity of North Africa. The Middle Eastern countries are, understandably, concerned about this trend, which they can do very little about.

(ii) The discovery of oil in Alaska, Indonesia, Australia and the North Sea

Recently, the chairman of Standard Oil (New Jersey) estimated that Alaska's North Slope reserves were between 30,000 million and 32,000 million barrels¹⁾ of crude.⁶²⁷

1) One barrel is equivalent to approximately 35 Imperial gallons.

This is equivalent to about three years total U.S.A. oil consumption, and would not greatly reduce reliance on Middle East supplies.

But the continual search in all parts of the world, in which 250 companies have invested more than \$1,000 million, is another reason why the existing producing countries are determined to obtain all the revenues they can, while they are able to.

(iii) The proliferation of smaller, but aggressive, independent companies

These companies first came on the scene when a group of U.S.A. independents secured 5 per cent of the old Anglo-Iranian concession in 1954. Then, in 1959, Oasis Oil Company, comprising Continental, Marathon and Amerada, found substantial reserves in Libya.

The same year, the U.S.A. introduced a quota system, to protect local producers, which effectively barred the independents from the world's most lucrative market for petroleum products. As a result, Continental (Conoco) and Marathon entered the European market on a substantial scale, and undercut the major international companies.

The success of these beginners spurred other companies to enter the international league, with the result that oil marketing is today far more complex and competitive than it used to be.

(iv) The growth of direct links - joint ventures - between the national oil companies of producing and consumer states

Traditionally, the big seven internationals, who for years enjoyed a kind of supra-national status, have acted as

catalyst, link and buffer between the producers and consumers. However, in an age in which all institutions are under attack, the oil 'establishment' does not enjoy a unique immunity. National governments are interfering more and more with oil-winning and marketing, for reasons of balance of payments considerations and/or security of supply.

France has controlled its oil market for years, encouraging French companies and prospecting for oil in areas within the French sphere of influence.

Italy has become significantly more independent in oil.

West Germany aims to have a quarter of its crude supply in German hands before long.

In Japan, which imports more oil than any other country, the government has declared that by 1985 at least 30 per cent of the supplies must be brought under Japanese ownership.

Even in South Africa the world-wide trend is noticeable. It is common knowledge that no significant deposits of mineral oil have yet been found in South Africa. All existing requirements for crude oil are satisfied by imports from the Persian Gulf. But oil is a basic natural resource that no modern state can do without. The government's concern about the complete reliance on foreign sources, capital and know-how is therefore understandable. In recent years, the government has demonstrated its resolution to lessen the degree of this dependence. The establishment of Sasol, the state-owned oil from coal refinery, was essentially the first step in this direction. This was followed by an active campaign to create a more favourable climate for local exploration. Lastly, the establishment of a supply agreement with the representative of a producing country, (the National Iranian Oil Company), and

the decision to erect local refining facilities in partnership with the supply company, are indicative of the latest developments in this respect.

(v) The growing impact of the Soviet Union on the world oil scene

Russia has a growing interest in Iraqi and Syrian oil. It has also established an agreement with Iran - a country which is anxious to diversify its markets.

The encouraging factor in this situation is that the Soviet Union, genuinely needing Middle East oil for its own industries, for Eastern Europe and for export, has a vested interest in the stability of the area. Its own vast reserves are in Central Asia, 2000 miles and more from the main consuming centres.

Doubt centres on Russia's marketing ambitions, which could provide another complication in a saturated market. Russia has been exporting about one fifth of her production to Italy, West Germany and Japan, as well as Eastern Europe. There are factors indicating that she wants to expand her markets in the West even further.

In South Africa, affiliates of some of the major international oil companies have for years been associated with the local industry. The first of these, the old Vacuum Oil Company (afterwards renamed Mobil Oil S.A. (Pty) Limited) established local offices as far back as 1897, marketing paraffins and lubricating oils.

Over the years, these companies have built up a very efficient industry in South Africa. In the process of doing so, vast sums of money have been invested here in marketing, distribution and production facilities which, in addition to being a substantial contribution to the

general economy, has paved the way for the local acquisition of new skills and foreign technologies. More recently, the establishment of refining facilities has made important contributions toward the conservation of foreign exchange.

Because of the relatively small local market and in the interest of optimum utilisation of available resources, the Government has followed a policy of restricting, not only the number of participants, but also the number of outlets, in the local market. Existing companies are encouraged, however, to build refineries, either alone or in combination with others, as soon as their share of the market justifies it.

The South African oil industry already supplies its products, for use other than as a fuel, to important and technologically progressive industries, notably the petrochemicals industry with its own very wide variety of products. Thus oil is an integral part of many aspects of modern life and is used, for example, to make the synthetic fibres used in textiles, most types of plastics, detergents, paints, synthetic rubbers, pesticides, weedkillers and fertilisers; and for lubricants and road making (with bitumen). The oil industry spends heavily on research into the various possible uses for oil products, and has substantial investment in industries such as petrochemicals. The value of oil to the economy, therefore, goes far beyond its use as a fuel, important though that is.

2.4.2 The historical pattern of demand for oil

Table 24 provides an indication of the growth in inland consumption (excluding bunkers) of the various refined oil products over the period 1910 to 1968. It highlights the rapid expansion of domestic oil demand,

TABLE 24: OIL CONSUMPTION BY PRODUCT IN THE REPUBLIC OF SOUTH AFRICA
AND SOUTH WEST AFRICA, 1910 - 1968

('000 BARRELS)

YEAR	PREMIUM PETROL	REGULAR PETROL	TOTAL PETROL	ILLUMINATING PARAFFIN	POWER PARAFFIN	LIGHT DIESEL	INDUSTRIAL AND FURNACE OILS	AVIATION GASOLINE	JET FUEL	LIQUEFIED PETROLEUM GAS	TOTAL OIL CONSUMPTION
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1910		23	23		216		2				241
1911		34	34		227		2				263
1912		54	54		251		2				307
1913		112	112		279		3				394
1914		109	109		285		5				399
1915		128	128		265		7				400
1916		142	142		266		43				451
1917		176	176		259		60				495
1918		140	140		154		80				374
1919		195	195		190		95				480
1920		278	278		221		115				614
1921		286	286		216		133				635
1922		270	270		237		150				657
1923		366	366		208		170				744
1924		476	476		270		188				934
1925		528	528		282		207				1,017
1926		859	859		282		230				1,371
1927		955	955		286		280				1,521
1928		1,240	1,240		363		325				1,928
1929		1,759	1,759		508		375				2,642
1930		1,642	1,642	322	121		422				2,507
1931		1,691	1,691	265	55		470				2,481
1932		1,680	1,680	283	88		520				2,571
1933		1,900	1,900	312	93		565				2,870
1934		2,199	2,199	388	189		612				3,388
1935		2,609	2,609	355	126		660				3,750
1936		3,228	3,228	385	166		710				4,489
1937		4,022	4,022	457	162		762				5,403
1938		4,534	4,534	439	186		807				5,966
1939		4,849	4,849	550	321	354	460	61			6,595
1940		4,869	4,869	491	292	294	414	104			6,464
1941		4,981	4,981	553	342	281	421	201			6,779
1942		4,057	4,057	873	373	285	406	560			6,554
1943		3,598	3,598	603	420	279	369	682			5,951
1944		3,591	3,591	655	497	295	395	704			6,137
1945		3,834	3,834	676	589	330	403	317			6,149
1946		5,537	5,537	760	794	411	443	100			8,045
1947		6,731	6,731	834	933	564	485	132			9,679
1948		7,861	7,861	952	1,114	733	548	165			11,373
1949		8,751	8,751	1,031	1,414	985	580	185			12,946
1950		8,839	8,839	1,054	1,603	1,201	501	201	5		13,404
1951		9,586	9,586	1,107	2,018	1,448	452	191	4		14,806
1952		9,917	9,917	1,136	2,138	1,612	421	206	16		15,446
1953		10,291	10,291	1,210	2,414	1,936	405	211	30		16,497
1954		10,673	10,673	1,311	2,611	2,356	441	227	21		17,640
1955		11,366	11,366	1,384	2,579	2,929	427	236	25		18,946
1956	170	11,673	11,843	1,461	2,618	3,535	389	269	38	6	20,159
1957	1,481	10,964	12,445	1,493	2,606	4,003	398	282	65	30	21,322
1958	2,145	10,907	13,052	1,552	2,436	4,609	606	290	59	49	22,653
1959	3,026	10,393	13,419	1,600	2,388	4,993	611	194	205	80	23,490
1960	3,920	10,035	13,955	1,650	2,331	5,608	612	205	299	106	24,766
1961	4,731	9,579	14,310	1,703	2,220	6,129	722	219	383	149	25,835
1962	5,589	9,145	14,734	1,783	2,124	6,822	810	228	433	209	27,143
1963	6,641	8,902	15,543	1,875	2,016	7,583	1,063	221	510	299	29,110
1964	8,416	8,615	17,031	1,946	1,912	8,747	1,172	262	564	386	32,020
1965	10,433	8,068	18,501	2,072	1,840	10,181	1,567	242	751	493	35,647
1966	12,069	7,694	19,763	2,211	1,757	11,258	2,219	217	1,068	579	39,072
1967	13,540	7,356	20,896	2,310	1,624	12,617	2,875	232	1,188	638	42,380
1968	15,540	6,965	22,505	2,393	1,485	13,980	3,157	212	1,362	752	45,846

especially in the post-war period. Over the last twenty years, total consumption increased at an average annual rate of 7.2 per cent.

It is to be observed that the fuel products listed under columns (1) to (10) of Table 24 are products which are normally consumed for energy-producing purposes. Certain other petroleum products, such as asphalt, solvents, special types of process products and lubricants, are naturally also products of crude petroleum, but, as they are consumed for purposes other than for the production of energy, they are not included in Table 24. Table 24 also excludes international bunkers, which will be dealt with in the section concerned with the import balances of petroleum products. It does, however, include domestic bunkers, comprising the consumption of oil by coastal shipping and local fishing.

The distinction made between the two grades of petrol is purely on the basis of their respective octane levels; premium petrol being the higher octane product. Illuminating paraffin is mostly used by lower income groups for the domestic purposes of heating, cooking and lighting. Power paraffin, until recently, was almost exclusively used by the agricultural tractor. In recent years, the product is also favoured as a clean-burning industrial heat fuel.

Light diesel, sometimes also called automotive diesel, is mostly used for providing mechanical energy in road motor vehicles, such as commercial vehicles, but also in tractors, diesel locomotives, earth moving equipment, marine engines and stationary machines. In addition, it is also consumed for heat-raising in small commercial establishments, and in air conditioning plant.

Three products are included under the heading of "industrial and furnace oils". The first of these, and also the lightest product of

the three, is usually called 'industrial diesel oil' to signify its use as a fuel in industrial (mostly stationary) plant. It is also used by marine engines and as a heat fuel. The second, a slightly heavier product, called 'light furnace oil' is, as denoted by its name, mostly used as a heat-fuel in furnaces. Lastly, 'heavy furnace oil', by volume the most important product, is predominantly a heat fuel used in industrial furnaces. This product is also used for the bunkering of large ships.

Aviation Gasoline is used as a fuel in piston-engined aircraft, while jet fuel, as implied in its name, is used by jets and turbo-prop aircraft.

Lastly, liquefied petroleum gas is a premium gas fuel which is very popular for heat-raising purposes among domestic, commercial and industrial consumers. The product is also used for lighting purposes, mainly by domestic consumers, although not as extensively as for heating and for cooking.

It is interesting to observe that whereas paraffin accounted for about 90 per cent of total oil demand in 1910, by 1968 the position had changed so that the two major fuels for road use (petrol and diesel) made up about 80 per cent of the total consumption in that year. This reflects, on the one hand, the structural change in energy demand in the domestic sector, which is now almost exclusively satisfied by electricity, as well as the rapidly growing needs of the road transport sector, on the other. The rapid increase in total oil consumption, especially since the war, is the result of the growth in the country's motor vehicle population.

2.4.3 Production of refined products

(i) Natal Cane By-Products Limited

The activities of this company, in the field of motor fuels, dates back to 1916, when patent rights were acquired for the production of Natalite Motor Fuel for South Africa.²⁵⁷ Natalite Motor Fuel was a mixture of industrial alcohol and ether, suitably denatured to comply with Excise regulations, the alcohol originally being obtained by the purchase of a local Durban distillery. By 1919, production reached 400,000 gallons per year, which represented 5.7 per cent of the total petrol consumption. The cost of denaturing the fuel was considerable and, as output was limited during the period of the First World War, the price of Natalite was much higher than ordinary petrol. During the post-war period and up to 1927, Natalite was able to compete with petrol in the local market, and indeed managed to hold successfully a Government Railways Motor Fuel Contract, against competitive tenderers, for over five years.²⁵⁷

In 1927, it was realised that a straight alcohol fuel would no longer be able to compete with petrol on a price basis, in view of the rising costs of the former and decreasing price of the latter. Consequently, extensive experiments were carried out with alcohol-petrol mixtures, culminating in the marketing of Union Motor Spirit early in 1928. This product originally required a large percentage of ether in the mixture to effect the necessary stability of alcohol and petrol but, by 1930, improved processes allowed the production of a motor spirit containing roughly 50 per cent denatured alcohol and 50 per cent petrol, plus certain additives. In 1933, the alcohol production process was further improved and factory

capacity doubled.

Production of Union Motor Spirit is restricted in relation to the quantity of the main raw material - molasses - available from Natal sugar estates. Part of the molasses is required for the manufacture of other alcohol products, such as methylated and rectified spirits, absolute and industrial alcohols, ethers etc. These are essential industrial products, the demand for which is rising each year. Consequently notwithstanding the gradually increasing acreage of sugar cane production, the annual output of Union Motor Spirit, which is very small in relation to total demand for petrol, is unlikely to vary very much in future.

Because of the small production, and as the product never obtained concessions in rail rates, its marketing was always restricted to Natal. The production of Union Motor Spirit can hardly be said to be of material consequence to the total supply of liquid fuels, but it is, nevertheless, interesting to realise the alcohol blend of Natal Cane By-Products Limited was probably the pioneer effort in utilising local resources for the production of a liquid motor fuel.²⁵⁷

(ii) South African Torbanite and Refining Company (Satmar)

Although torbanite, an oil-bearing shale, was discovered in South Africa as far back as 1893, its exploitation only commenced during the Thirties after a decision by the British Burma Petroleum Company, in 1932, to investigate the occurrence of shale and torbanite in the Eastern Transvaal.⁶³⁷

In 1934, this company, in collaboration with the Anglo-Transvaal Consolidated Investment Company, formed Satmar to produce oil from torbanite shale. During the same year,

mining and retorting installations were erected at the farm Mooifontein, eleven miles from Ermelo in the Eastern Transvaal, and a purification plant at Boksburg, 150 miles away.

The torbanite shale, crushed to small sizes, was fed to the retorting units, where it was heated. This treatment evaporated the oil, which was condensed into a crude oil and was subsequently transported in rail tank wagons to the Satmar refinery at Boksburg. The large supply of medium grade coal overlying the torbanite deposit provided an adequate fuel for retort heating, and a surplus was generally available for the local market.

At the Satmar refinery the crude oil was refined, by means of conventional processes, to produce petrol, paraffin, naptha and bitumen. The petrol, marketed under the name of Satmar, was eventually a mixture of torbanite petrol, alcohol and benzol; the latter being obtained from the coke installations of Iscor. The octane rating of the fuel, thus produced, was relatively high.

Production statistics on Satmar-petrol are not available, and the relevant statistics on the production of crude oil can only be obtained for certain years. From these statistics it is clear, however, that the production of crude oil increased from about six million gallons in 1944 to 9 million gallons in 1956. Thereafter, production gradually declined with the depletion of the torbanite shale deposits.

In 1957, the production of Satmar-petrol was taken over by Sasol, and the crude oil processed by the Boksburg refinery was supplemented by crude oil imported from overseas and shipped through Durban. In 1960, all torbanite mining

operations ceased and imported crude became the sole source of raw material. During the same year, agreement was reached with the five biggest oil companies for the supply of crude over a period of 15 years.

The total annual local production of motor fuels in South Africa for the period 1927 - 1947 is estimated at around 5 to 6 million gallons a year, and for the period 1947 - 1953 at approximately 7 to 9 million gallons a year. As this represents less than 5 per cent of annual total domestic consumption for that period, it may be concluded that local production did not significantly influence imports of refined product prior to 1954.¹⁹⁷

(iii) Mobil Oil Southern Africa (Pty) Limited (Mobilref)

The building of a conventional oil refinery in Durban had already been actively considered before the War. The outbreak of the War temporarily interrupted negotiations, which were re-opened in 1948. A commission of inquiry appointed by the afore-mentioned company investigated the siting of the proposed refinery and recommended that it be erected in Durban. The plant took two years to build, at a cost of R14 million, and came on stream in January 1954.

The refinery was designed to handle crude oil received in ocean tankers from the Persian Gulf, and to distribute some of its refined products by ocean tanker to South African ports, or to other ports in Africa. It was also designed so as to yield the optimum proportion of light products (such as petrol, paraffins and diesel), for which a relatively high inland demand exists.

The various refined oil products produced from crude petroleum can be listed from light to heavy as follows:

Refinery gas
Liquefied petroleum gas
Naptha
Petrol
Solvents
Jet fuel
Power paraffin
Light diesel
Light furnace oil
Heavy furnace oil
Waxes
Bitumen

These hydrocarbons have different boiling points, which is the principle applied by a refinery to separate the various fractions contained in crude oil. This process is normally called 'atmospheric distillation'. The distribution and quality of refined runs can further be varied by processes known as 'reforming' and 'catalytic-cracking'.

The Mobil refinery was initially designed to process 200 million gallons a year of crude oil, but successive expansions have raised its capacity to 780 million gallons a year in 1970.

(iv) South African Coal, Oil and Gas Corporation Limited (Sasol)

The Sasol refinery is situated at Sasolburg in the North-Eastern Orange Free State, fifty miles from Johannesburg and 17 miles from Vereeniging.. The 3000 morgen site lies atop

a large coalfield close to the banks of the Vaal River, thus providing both coal and water for the production processes. Johannesburg and the concentrated marketing area of the Witwatersrand are within easy distance.

The Sasol production process consists basically of the gasification of coal by steam and oxygen into carbon monoxide and hydrogen. The raw gas is then processed into hydrocarbons and chemical by-products with the aid of catalysts, applying an improved version of the original Fisher-Tropsch technology.

Apart from oil products, such as petrol, diesel and furnace oil, the plant is also capable of manufacturing a wide range of petrochemical products and feedstocks for important allied chemical industries, such as the plastics, synthetic rubber, and fertiliser industries.

Sasol was planned with the aim of producing 55 million gallons of petrol, 4.3 million gallons of diesel and 2.3 million gallons of furnace oil. It gradually became clear that the processes involved were incapable of reaching these targets, and additional investment became necessary.

With the decision to enter the petrochemical field, a naphtha steam cracker was erected. This allowed Sasol to enter the ethylene and butadiene field in order to produce the raw material required for the synthetic materials industry. By-product petrol was also produced, increasing Sasol's hydrocarbon output.

So, although Sasol's total production of refined petroleum products is currently estimated at 120 million gallons a year, it is estimated that the yield of petroleum products derived from coal is only in the order of 62 million

gallons a year.⁶⁴⁷ This represents about 4 per cent of total refined demand in 1968.

The oil-from-coal plant of Sasol has built various extensions to enable it to meet the demands of the expanding chemical industry. A pipeline, costing R30 million, was further completed early in 1966 and supplies coal-gas from Sasol to industrial users on the Witwatersrand. The name of the affiliate operating the gas plant is the South African Gas Distribution Corporation Limited (Gascor).

Lastly, Sasol also has interests in the Southern Oil Exploration Corporation Limited (Soekor) and in National Petroleum Refiners of South Africa (Pty) Limited (Natref).

(v) The Shell and BP South African Refineries (Pty) Ltd. (Sapref)

The Sapref refinery, built jointly by Shell South Africa (Pty) Limited (Shell) and BP Southern Africa (Pty) Limited (BP) at a cost of R32 million, came on stream at Reunion in Durban during October 1963. The refinery was initially designed to process three million tons of crude oil (700 million gallons) a year.

As with the Mobil-refinery, Sapref receives her crude in ocean tankers from the Middle East. By means of a system of pipelines, crude oil is pumped over a distance of eight miles to the refinery from Durban harbour, while finished product is pumped back to the storage tanks located in the harbour. Refined product is also pumped from the two Durban refineries to the Reef, by means of a pipeline specially built to carry finished product.

The current capacity of the Shell-BP refinery is estimated at 1,300 million gallons a year.

(vi) Caltex Oil (S.A.) Limited (Calref)

The Caltex refinery, built at a cost of R22 million at Killarney, about eight miles from Cape Town, came on stream during July 1966. It is estimated that the current capacity of the refinery is in the order of 550 million gallons a year.

(vii) National Petroleum Refiners of South Africa (Pty) Limited (Natref)

The R60 million Natref refinery is nearing completion at Sasolburg in the Orange Free State. Natref is a joint venture between the South African Government (represented by Sasol), Total Refining South Africa (Pty) Limited (Torsa) and the National Iranian Oil Company (NIOC). Their respective shares in the venture are $52\frac{1}{2}$ per cent, 30 per cent and $17\frac{1}{2}$ per cent. Total Refining South Africa (Pty) Limited was specially formed for this purpose by the parent company of Total, the French company, Compagnie Francaise Des Petroles.

NIOC, representing the Iranian Government, has undertaken to supply crude oil, which will be brought from the Persian Gulf by tankers and transported to the refinery site by means of a crude oil pipeline which is currently under construction between Durban and Sasolburg. It is estimated that Natref will eventually be able to process 2.8 million tons (700 million gallons) of crude oil a year.

Table 25 provides the history, since 1916, of the production of refined petroleum products in South Africa. The data were obtained in a private capacity from the Department of Customs and Excise. From this table, it is clear that production from local resources has made little contribution towards the total demand (see Table 24), and that important progress towards refining self-sufficiency has been made by

TABLE 25: LOCAL PRODUCTION OF REFINED OIL,
1916 - 1968

YEAR	PETROL	ALL PARAFFINS	DISTILLATE FUELS	RESIDUAL FUELS	LIQUEFIED PETROLEUM GAS	REFINERY GAS	TOTAL ('000 GALLONS)	TOTAL ('000 BARRELS)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1916	100						100	3
1917	200						200	7
1918	300						300	9
1919	400						400	11
1920	600						600	17
1921	800						800	23
1922	1,200						1,200	34
1923	1,600						1,600	46
1924	2,000						2,000	57
1925	3,000						3,000	86
1926	4,000						4,000	114
1927	5,000						5,000	143
1928	5,200						5,200	149
1929	5,500						5,500	157
1930	5,800						5,800	166
1931	6,100						6,100	174
1932	6,400						6,400	183
1933	6,700						6,700	191
1934	7,000						7,000	200
1935	7,300						7,300	209
1936	7,600						7,600	217
1937	7,900						7,900	226
1938	8,200						8,200	234
1939	8,500						8,500	243
1940	8,500						8,500	243
1941	8,500						8,500	243
1942	8,500						8,500	243
1943	8,500						8,500	243
1944	8,585						8,585	245
1945	8,577						8,577	245
1946	9,448						9,448	270
1947	7,054						7,054	202
1948	8,316						8,316	238
1949	9,116						9,116	260
1950	9,406						9,406	269
1951	8,717						8,717	249
1952	8,705						8,705	249
1953	9,859						9,859	282
1954	80,344		83,650				163,994	4,686
1955	108,151		114,205				222,356	6,353
1956	117,960		125,621		210		243,791	6,965
1957	126,969		137,312		1,050		265,331	7,581
1958	147,634		163,652		1,715		313,001	8,943
1959	147,328		71,117	85,580	2,800		306,825	8,766
1960	151,616		69,069	78,177	3,710		302,572	8,645
1961	166,271	42,807	73,890	97,808	5,215		385,991	11,028
1962	185,611	48,415	83,659	99,297	7,315		424,297	12,123
1963	230,717	52,408	118,721	160,438	10,465		572,749	16,364
1964	448,235	59,884	284,822	391,553	13,510		1,198,004	34,229
1965	443,803	61,798	283,245	339,723	17,255		1,146,004	32,743
1966	521,510	68,672	331,631	397,307	20,265		1,339,385	38,267
1967	660,452	70,905	436,669	577,826	22,330	3,570	1,771,752	50,620
1968	665,792	64,539	447,783	671,843	26,320	9,415	1,885,692	53,876

the conventional oil refineries since 1954.

2.4.4 The import balance of refined petroleum products

Tables 26 to 28 provide all the relevant statistics on the imports of refined oil products, re-exports of imported oil and the exports of locally produced product. In Table 29 all this information is condensed, and the import balance of refined petroleum products constructed. Sources of information are the various Trade and Shipping Yearbooks since 1910, of the Department of Customs and Excise, and, in later years, the various Imports and Exports Yearbooks.⁶⁵⁷

Table 26 illustrates the rapidly rising trend in imports of refined products up to the year 1954, the year in which the Mobil refinery came on stream. Since that year, the rising levels of imports were stemmed, only to increase sharply in 1956 again, as a result of the Suez-crisis in that year and the resulting unprecedented demand for bunkers at South African ports. This trend was repeated in 1968, after the second Suez closure in June 1967.

Table 28 shows that it was even possible to export substantial volumes of locally refined product, notably heavy furnace oil, after the coming on stream of the Shell-BP refinery in 1963.

Table 29 illustrates the adverse trade gap in refined petroleum products experienced up to 1966. The brackets, provided in respect of the balances for the years 1967 and 1968, indicate that for those two years the country managed, for the first time, to export more refined product than was actually imported. This, again, was the result of the Suez-closure in 1967.

It may, therefore, be concluded that the country is, for all

TABLE 26: IMPORTS OF OIL, REPUBLIC OF SOUTH AFRICA
AND SOUTH WEST AFRICA, 1910 - 1968

YEAR	PETROL	ILLUMINATING PARAFFIN	POWER PARAFFIN	LIGHT DIESEL	HEAVY DIESEL	FURNACE FUELS	OTHER	TOTAL ('000 GALLONS)	TOTAL ('000 BARRELS)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1910	833	8,649					64	9,546	273
1911	1,674	9,917					46	11,637	332
1912	2,023	11,232					93	13,348	381
1913	4,260	10,299					130	14,689	420
1914	4,168	9,598					164	13,930	398
1915	5,217	9,665					366	15,248	436
1916	5,629	9,348					5,590	20,567	588
1917	6,967	10,097					6,969	24,033	687
1918	5,526	5,988					4,930	16,444	470
1919	7,727	7,387					884	15,998	457
1920	11,012	8,619					1,774	21,405	612
1921	11,339	8,402					7,572	27,313	780
1922	10,672	9,210					1,290	21,172	605
1923	14,487	8,087					2,083	24,657	704
1924	18,875	10,505			6,038		11	35,429	1,012
1925	20,890	10,970			1,439		54	33,353	953
1926	34,004	10,953			4,585		59	49,601	1,417
1927	37,786	11,126			6,673		22	55,607	1,589
1928	49,106	14,121			11,481		68	74,776	2,136
1929	69,643	19,754			13,045		58	102,500	2,929
1930	65,023	17,369			16,980		101	99,473	2,842
1931	66,943	10,177	2,280		15,704		121	95,225	2,721
1932	66,526	10,901	3,621		12,660		127	93,835	2,681
1933	75,232	11,968	3,806		19,846		135	110,987	3,171
1934	92,652	14,917	7,763		19,335		105	134,772	3,851
1935	107,941	13,650	5,183		39,761		193	166,728	4,764
1936	126,119	14,795	6,822		61,993		225	209,954	5,999
1937	144,750	17,559	6,688		89,963		246	259,206	7,406
1938	155,215	16,084	7,652		105,305		222	285,278	8,151
1939	180,558	21,526	13,665		132,841		233	348,823	9,966
1940	171,652	18,513	11,698		321,199		427	523,489	14,957
1941	168,190	17,565	10,696		289,012		343	485,806	13,880
1942	169,579	21,286	15,515		387,195		134	593,709	16,963
1943	150,861	24,642	15,705		230,819		270	422,297	12,066
1944	149,296	27,200	17,007		55,480		391	249,374	7,125
1945	131,662	23,894	20,966		75,685		432	252,639	7,218
1946	206,203	27,313	33,759		33,206	67,694	509	368,684	10,534
1947	231,891	31,450	32,291		56,075	38,298	754	390,759	11,165
1948	271,403	30,355	43,057		75,889	96,910	398	518,012	14,800
1949	315,431	38,763	55,134		79,355	89,206	637	578,526	16,529
1950	316,349	36,502	63,388		120,714	69,616	450	607,019	17,343
1951	327,737	41,793	72,439		113,213	104,336	727	660,245	18,864
1952	347,557	43,991	74,737	65,152	37,481	77,997	438	647,353	18,496
1953	363,942	42,096	84,582	65,365	34,639	59,023	473	650,120	18,575
1954	300,358	43,320	95,232	69,236	24,639	47,611	672	581,068	16,602
1955	316,614	41,075	89,951	83,506	20,734	39,851	861	592,592	16,931
1956	340,810	43,153	91,466	111,753	34,134	99,777	1,012	722,105	20,632
1957	314,557	40,667	86,679	120,962	42,301	171,963	848	777,977	22,228
1958	345,010	51,311	81,260	127,329	16,609	36,359	775	658,653	18,819
1959	338,978	42,683	66,296	135,196	8,594	47,349	898	639,994	18,286
1960	343,638	45,200	66,084	138,461	8,488	39,584	4,494	645,949	18,456
1961	358,710	49,348	61,292	154,425	1,300	49,991	1,062	676,128	19,318
1962	364,543	50,743	55,430	161,669	6,025	54,815	5,551	698,776	19,965
1963	322,622	57,078	53,195	151,279	6,064	30,790	6,345	627,373	17,925
1964	200,919	61,069	50,861		91,445	926	1,338	406,558	11,616
1965	212,964	93,585			117,561	20,403		444,513	12,700
1966	236,261	116,026			155,689	4,557		512,533	14,644
1967	111,453	117,910			111,782	148,391		489,536	13,987
1968	196,619	120,100			115,851	242,527		675,097	19,288

TABLE 28: EXPORTS OF SOUTH AFRICAN PRODUCED REFINED OIL,
1952 - 1968

YEAR	PETROL	ALL PARAFFINS	DISTILLATE FUELS	RESIDUAL FUEL OILS	OTHER	TOTAL ('000 GALLONS)	TOTAL ('000 BARRELS)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1910							
1911							
1912							
1913							
1914							
1915							
1916							
1917							
1918							
1919							
1920							
1921							
1923							
1924							
1925							
1926							
1927							
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1939							
1940							
1941							
1942							
1943							
1944							
1945							
1946							
1947							
1948							
1949							
1950							
1951							
1952					37	37	1
1953					88	88	3
1954	2,791		8,519	30,174	244	41,728	1,192
1955	3,765	275	24,037	48,973	195	77,245	2,207
1956	6,046	860	20,320	60,384	194	87,804	2,509
1957	5,901	103	24,293	51,249	247	81,793	2,337
1958	12,803	65	23,205	61,639	210	97,922	2,798
1959	8,522	8,233	27,598	61,184	622	106,159	3,033
1960	3,019	3,804	9,064	54,239	1,233	71,359	2,039
1961	14	485	1,216	61,875	1,610	65,200	1,863
1962	1	27	1,146	64,245	2,042	67,461	1,927
1963	42	2,502	10,962	95,196	3,184	111,886	3,197
1964	1,229	6,269	30,076	314,625		352,199	10,063
1965	849	6,439	25,700	236,334		269,322	7,695
1966	15,386	20,888	55,194	290,922		382,390	10,925
1967	21,421	20,759	89,725	556,675		688,580	19,674
1968	18,685	19,495	71,612	734,779		844,571	24,131

TABLE 29: IMPORT BALANCE OF OIL, REPUBLIC OF SOUTH AFRICA
AND SOUTH WEST AFRICA, 1910 - 1968

('000 BARRELS)

YEAR	IMPORTS	RE-EXPORTS	EXPORTS	TOTAL EXPORTS	IMPORT BALANCE
	(1)	(2)	(3)	(4) = (2) + (3)	(5) = (1) - (4)
1910	273	1		1	272
1911	332	1		1	331
1912	381	4		4	377
1913	420	6		6	414
1914	398	7		7	391
1915	436	11		11	425
1916	588	19		19	569
1917	687	16		16	671
1918	470	12		12	458
1919	457	14		14	443
1920	612	17		17	595
1921	780	59		59	721
1922	605	1		1	604
1923	704	3		3	701
1924	1,012	11		11	1,001
1925	953	63		63	890
1926	1,417	12		12	1,405
1927	1,589	11		11	1,578
1928	2,136	30		30	2,106
1929	2,929	58		58	2,871
1930	2,842	60		60	2,782
1931	2,721	120		120	2,601
1932	2,681	47		47	2,634
1933	3,171	108		108	3,063
1934	3,851	115		115	3,736
1935	4,764	339		339	4,425
1936	5,999	367		367	5,632
1937	7,406	227		227	7,179
1938	8,151	129		129	8,022
1939	9,966	73		73	9,893
1940	14,957	96		96	14,861
1941	13,880	249		249	13,631
1942	16,963	634		634	16,329
1943	12,066	625		625	11,441
1944	7,125	110		110	7,015
1945	7,218	158		158	7,060
1946	10,534	1,733		1,733	8,801
1947	11,165	2,129		2,129	9,036
1948	14,800	3,100		3,100	11,700
1949	16,529	3,706		3,706	12,823
1950	17,343	4,105		4,105	13,238
1951	18,864	3,987		3,987	14,877
1952	18,496	2,770	1	2,771	15,725
1953	18,575	2,690	3	2,693	15,882
1954	16,602	2,477	1,192	3,669	12,933
1955	16,931	1,817	2,207	4,024	12,907
1956	20,632	3,330	2,509	5,839	14,793
1957	22,228	6,895	2,337	9,232	12,996
1958	18,819	1,843	2,798	4,641	14,178
1959	18,286	1,445	3,033	4,478	13,808
1960	18,456	1,517	2,039	3,556	14,900
1961	19,318	1,879	1,863	3,742	15,576
1962	19,965	1,630	1,927	3,557	16,408
1963	17,925	1,367	3,197	4,564	13,361
1964	11,616	363	10,063	10,426	1,190
1965	12,700	-	7,695	7,695	5,005
1966	14,644	-	10,925	10,925	3,719
1967	13,987	-	19,674	19,674	(5,687)
1968	19,288	-	24,131	24,131	(4,843)

practical purposes, self-sufficient in refining capacity. This is compatible with Government policy of encouraging local refining for balance of payments reasons, so that the cost of refining is incurred within this country instead of abroad. This policy also stimulates secondary and associated industries, such as petrochemicals, adds to security because it is easier to switch sources of crude oil than sources of products, and gives rise to substantial inflows of foreign capital for refinery construction. It also enables advantage to be taken of the increase in the size of tankers, which, for crude oil, are much larger than tankers built to carry products.

There will always be trade in oil products between countries, as well as between companies, in order to balance the requirements of markets with the output of particular products from refineries and the yields of different crude oils; this exchange produces a more economic supply pattern than could be achieved by complete self-sufficiency. The Government's objective has been that local refining should suffice to cover inland demand and bunkers in total, with marginal product imports balanced by exports; it was expected that the proceeds of the product exports would generally be more than sufficient to cover the cost of imports.

2.4.5 The exploration for oil in Southern Africa

In earlier paragraphs, indications were given as to the extent of the country's dependence upon imported sources of liquid fuel. Although net imports of refined products have decreased considerably over the last few years, South Africa is still almost exclusively reliant on outside sources for her requirements in crude oil. The bill for liquid fuel (crude and refined) importation amounted to about R100 million in 1968.⁶⁵⁷

Today, oil is the product most likely to be used in international politics for exerting pressure, since it is the sole source of energy for road transportation and military purposes. Because all oil sources are known and localised, effective blockade is possible, as was illustrated so vividly in the case of Rhodesia, a few years ago.

These factors have initiated a number of measures in South Africa which are designed to lessen the dependence upon outside sources of petroleum. Among these are the current serious exploration for oil, and such measures as stockpiling, the acquisition of an adequate oil tanker fleet (the movements of which are locally controlled), and the signing of supply agreements with producer countries. Recently, it also became known that the authorities are actively considering the building of a second oil from coal plant, with the possibility of others.

The search for oil in South Africa was given strong impetus with the establishment of the Southern Oil Exploration Corporation (Pty) Limited (Soekor). Soekor is a government sponsored and government financed organisation, its main terms of reference being: ⁶⁶⁷

- (i) to expedite and accelerate the search for oil in the Republic of South Africa;
- (ii) to seek maximum support and co-operation from technically and financially competent private concerns (local and overseas);
- (iii) to undertake exploration itself; and
- (iv) to assist other oil prospecting lease holders.

Southern Oil Exploration Corporation (SWA) (Pty) Limited (Swakor) is the counterpart of Soekor in South West Africa. It is an autonomous company established, with the concurrence of the Administration of South

West Africa, to co-ordinate the search for oil in that territory. With this end in view, Swakor is also financially assisted by the Administration.

The Administration granted Swakor prospecting rights over certain areas, both onshore and within the territorial waters and continental shelf of South West Africa.

Soekor and Swakor together hold leases over: ^{66/}

- (i) onshore areas in the Republic of South Africa, some 350,000 square miles in extent, of which about 200,000 square miles could be said to justify active exploration;
- (ii) the continental shelf of the Republic of South Africa, some 70,000 square miles;
- (iii) about 200,000 square miles onshore in South West Africa, of which some 50,000 square miles are worth exploring;
- (iv) roughly 25,000 square miles of offshore areas (continental shelf) off South West Africa.

Soekor and Swakor do not hold the prospecting rights in all areas in the Republic or South West Africa; there are ten other prospecting leaseholders, of which five in the Republic have some active form of collaboration with Soekor. ^{66/}

On the continental shelf of the Republic, Soekor has 12 offshore lessees, including most of the major oil companies, and two well-known independent concerns. The whole offshore area has been sub-leased. South Africa is unique in the respect that offshore exploration is being undertaken where no oilfields have, as yet, been found on the adjacent mainland.

In October 1968, Soekor awarded, in total, 8 offshore areas, or blocks, to international and local lessees.

Drilling is currently in progress both on land and offshore. Although evidence of the presence of hydrocarbons has been found inland, no significant strikes have yet been made.

The most dramatic discovery so far is the gas strike on the continental shelf off Plettenberg Bay, by the oil drilling ship, "Glomar Sirte". The find is capable of yielding 25 million cubic feet of natural gas a day from its upper zone, and an additional 10 million cubic feet from a lower reservoir. Experts have stated that the energy equivalent of this gas is about 400,000 tons of coal a year.²⁴⁷ So, although the gas discovery is insignificant from an energy supply point of view, it is most encouraging from the exploration angle, as it has now been proved that geological conditions on the continental shelf are favourable for the presence of hydrocarbons. In other parts of the world, notably in Canada and Australia, exploratory drilling was in progress for 10 years, and more, before significant deposits of crude oil were found.

2.4.6 The motor vehicle population

In Table 24 it was observed that the combined volume of petrol and diesel, the two major fuels used by road motor vehicles, represented about 80 per cent of total inland demand in 1968. Any attempt to forecast the future demand for oil must therefore, of necessity, start with an examination of the country's motor vehicle population.

In a previous study of this nature,¹⁹⁷ all the available official statistics on the motor vehicle population,⁶⁷ since 1920, were collated, examined and the deficiencies outlined, so that there is little need to repeat them again. The two main sources of error in official series were, firstly, that, for some years, population figures related to full calendar years, and, for others, it represented the population registered

as at 30th June of a particular year. Secondly, a substantial double-counting error existed in statistics prior to 1961, because of certain weaknesses in the method of enumeration in use prior to that year.¹⁹⁷

The inaccuracies in the available historical statistics were corrected, and adjusted series were provided in the source mentioned above.¹⁹⁷ The new estimates of the motor vehicle population, so established, have subsequently been used in other studies relating to problems of road transport.⁶⁸⁷

In Tables 30 to 32 the required data on the motor vehicle population for the Republic of South Africa and South West Africa are summarised, and further brought up to date in the light of the latest available official information.⁶⁹⁷

It hardly needs to be emphasised that the size of a country's motor vehicle population is largely determined by the number of people and, especially, the real standard of living of the people in the country concerned. This fact was soundly illustrated by Van der Dussen⁷⁰⁷ who made a correlation analysis between the per capita national incomes of those 32 countries possessing, in aggregate, 95 per cent of all motor vehicles in the world, and the per capita motor vehicle ownership in those countries. A (Spearman) rank correlation co-efficient of 0.93 was obtained, which is indicative of this relationship.

It is only logical to expect that in South Africa, where the per capita income of the population has risen very sharply in recent years because of rapid growth in the economy generally, a rapid increase in the numbers of motor vehicles has been experienced. From column (6) of Table 32, it is evident that the total vehicle population has doubled itself over the last 10 years, or alternatively, has grown at an average annual rate of 7.5 per cent. In section 2.4.2 above, it was observed

**TABLE 30: REPUBLIC OF SOUTH AFRICA, MID-YEAR ESTIMATES OF THE
TOTAL MOTOR VEHICLE POPULATION, 1921-1968**

YEAR	MOTORS	BUSES AND MINI-BUSES	COMMERCIAL VEHICLES	MOTOR CYCLES	TOTAL
	(1)	(2)	(3)	(4)	(5)
1921	25,521	124	1,140	15,251	42,036
1922	27,997	158	1,483	15,059	44,697
1923	34,014	196	1,787	15,822	51,819
1924	44,639	281	2,550	18,444	65,914
1925	56,668	400	3,636	21,664	82,368
1926	71,510	551	4,955	25,577	102,593
1927	87,830	704	7,268	30,043	125,845
1928	103,936	890	10,045	33,273	148,144
1929	120,829	1,099	12,948	34,740	169,616
1930	131,640	1,278	15,804	34,333	183,055
1931	135,258	1,339	17,539	32,586	186,722
1932	139,086	1,227	17,903	31,866	190,082
1933	146,490	1,117	18,349	32,006	197,962
1934	166,578	1,149	21,813	32,053	221,593
1935	195,483	1,212	27,045	31,471	255,211
1936	225,725	1,250	32,536	30,055	289,566
1937	259,330	1,458	39,202	28,143	328,133
1938	286,038	1,694	45,778	25,951	359,461
1939	303,211	1,747	50,844	23,919	379,721
1940	310,176	1,719	54,347	22,567	388,809
1941	310,823	1,840	57,624	20,270	390,557
1942	301,968	1,997	62,602	19,044	385,611
1943	286,626	2,129	65,077	18,886	372,718
1944	279,130	2,229	66,192	18,401	365,952
1945	276,606	2,326	68,624	18,798	366,354
1946	284,875	2,574	75,572	20,490	383,511
1947	314,900	3,305	86,590	21,610	426,405
1948	365,315	3,928	102,872	21,856	493,971
1949	410,759	4,204	117,521	22,203	554,687
1950	435,480	4,397	122,987	22,218	585,082
1951	451,595	4,559	126,969	22,379	605,502
1952	467,142	4,636	132,994	22,868	627,640
1953	487,053	4,731	139,119	23,976	654,879
1954	506,476	4,915	145,821	25,112	682,324
1955	528,234	5,186	156,493	26,527	716,440
1956	556,026	5,610	170,081	31,324	763,041
1957	600,465	6,693	182,490	39,999	829,647
1958	656,335	8,489	191,541	49,329	905,694
1959	705,755	10,563	197,361	64,206	977,885
1960	762,629	13,430	203,670	76,137	1,055,866
1961	803,305	15,452	208,259	79,835	1,106,851
1962	842,701	17,668	217,520	83,523	1,161,412
1963	923,178	18,662	236,892	85,550	1,264,282
1964	1,022,573	19,767	265,674	90,600	1,398,614
1965	1,125,100	20,970	296,600	98,650	1,541,320
1966	1,222,492	27,096	319,984	98,462	1,668,034
1967	1,323,000	28,000	346,000	105,000	1,802,000
1968	1,415,000	29,000	373,000	112,000	1,929,000

**TABLE 31: SOUTH WEST AFRICA, MID-YEAR ESTIMATES OF THE
TOTAL MOTOR VEHICLE POPULATION, 1921 to 1968**

YEAR	MOTORS	BUSES AND MINI-BUSES	COMMERCIAL VEHICLES	MOTOR CYCLES	TOTAL
	(1)	(2)	(3)	(4)	(5)
1921	438	2	56	228	724
1922	481	2	73	225	781
1923	585	3	88	237	913
1924	767	4	127	276	1,174
1925	975	6	180	324	1,485
1926	1,237	8	246	384	1,875
1927	1,514	11	360	451	2,336
1928	1,793	13	497	500	2,803
1929	2,086	17	642	523	3,268
1930	2,271	19	784	518	3,592
1931	2,335	20	869	492	3,716
1932	2,404	19	888	482	3,793
1933	2,533	17	910	485	3,945
1934	2,882	17	1,084	487	4,470
1935	3,384	18	1,345	478	5,225
1936	3,910	19	1,620	457	6,006
1937	4,494	22	1,953	428	6,897
1938	4,959	26	2,280	394	7,659
1939	5,265	27	2,538	363	8,193
1940	5,395	26	2,615	336	8,372
1941	5,418	28	2,658	294	8,398
1942	5,256	31	2,713	258	8,258
1943	4,986	33	2,756	252	8,027
1944	4,857	34	2,858	256	8,005
1945	4,817	35	3,121	269	8,242
1946	4,980	39	3,714	306	9,039
1947	5,532	47	4,427	332	10,338
1948	6,418	56	5,228	337	12,039
1949	7,237	60	5,950	343	13,590
1950	7,704	63	6,287	345	14,399
1951	8,019	66	6,536	349	14,970
1952	8,314	65	6,785	358	15,522
1953	8,690	65	7,045	378	16,178
1954	9,063	66	7,394	395	16,918
1955	9,481	70	7,965	417	17,933
1956	10,043	78	8,704	495	19,320
1957	10,468	117	10,032	634	21,251
1958	12,157	148	10,980	755	24,040
1959	12,949	258	11,526	806	25,539
1960	13,763	360	12,313	874	27,310
1961	14,341	405	12,517	1,004	28,267
1962	13,843	453	12,674	845	27,815
1963	14,070	512	13,267	831	28,680
1964	15,085	598	14,719	872	31,274
1965	16,512	662	16,443	941	34,558
1966	18,000	800	17,500	1,050	37,350
1967	19,500	900	19,500	1,200	41,100
1968	21,000	1,000	20,000	1,390	43,390

TABLE 32 : REPUBLIC AND SOUTH WEST AFRICA, MID-YEAR ESTIMATES OF THE
TOTAL MOTOR VEHICLE POPULATION, 1921 to 1968

YEAR	MOTORS	BUSES	COMMERCIAL VEHICLES	TRACTORS	MOTOR CYCLES	GRAND TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)
1921	25,959	126	1,196	550	15,479	43,310
1922	28,478	160	1,556	699	15,284	46,177
1923	34,599	199	1,875	883	16,059	53,615
1924	45,406	285	2,677	1,068	18,720	68,156
1925	57,643	406	3,816	1,253	21,988	85,106
1926	72,747	559	5,201	1,439	25,961	105,907
1927	89,344	715	7,628	1,883	30,494	130,064
1928	105,729	903	10,542	2,583	33,773	153,530
1929	122,915	1,116	13,590	3,284	35,263	176,168
1930	133,911	1,297	16,588	3,984	34,851	190,631
1931	137,593	1,359	18,408	4,530	33,078	194,968
1932	141,490	1,246	18,791	4,923	32,348	198,798
1933	149,023	1,134	19,259	5,315	32,491	207,222
1934	169,460	1,166	22,897	5,708	32,540	231,771
1935	198,867	1,230	28,390	6,125	31,949	266,561
1936	229,635	1,269	34,156	6,567	30,512	302,139
1937	263,824	1,480	41,155	7,010	28,571	342,040
1938	290,997	1,720	48,058	8,189	26,345	375,309
1939	308,476	1,774	53,382	10,105	24,282	398,019
1940	315,571	1,745	56,962	12,017	22,903	409,198
1941	316,241	1,868	60,282	13,922	20,564	412,877
1942	307,224	2,028	65,315	15,809	19,302	409,678
1943	291,612	2,162	67,833	17,791	19,138	398,536
1944	283,987	2,263	69,050	19,670	18,657	393,627
1945	281,423	2,361	71,745	21,439	19,067	396,035
1946	289,855	2,613	79,286	23,382	20,796	415,932
1947	320,432	3,352	91,017	25,773	21,942	462,516
1948	371,733	3,984	108,100	33,225	22,193	539,235
1949	417,996	4,264	123,471	44,813	22,546	613,090
1950	443,184	4,460	129,274	54,218	22,563	653,699
1951	459,614	4,625	133,505	66,308	22,728	686,780
1952	475,456	4,701	139,779	78,741	23,226	721,903
1953	495,743	4,796	146,164	86,368	24,354	757,425
1954	515,539	4,981	153,215	93,082	25,507	792,324
1955	537,715	5,256	164,458	100,268	26,944	834,641
1956	566,069	5,688	178,785	105,982	31,819	888,343
1957	610,933	6,810	192,522	112,406	40,633	963,304
1958	668,492	8,637	202,521	119,511	50,084	1,049,245
1959	718,704	10,821	208,887	123,647	65,012	1,127,071
1960	776,392	13,790	215,983	127,806	77,011	1,210,982
1961	817,646	15,857	220,776	134,390	80,839	1,269,508
1962	856,544	18,121	230,194	138,929	84,368	1,328,156
1963	937,248	19,174	250,159	146,000	86,381	1,438,962
1964	1,037,658	20,365	280,393	155,500	91,472	1,585,388
1965	1,141,612	21,632	313,043	166,000	99,591	1,741,878
1966	1,240,492	27,896	337,484	188,000	99,512	1,893,384
1967	1,342,500	28,900	365,500	204,000	106,200	2,047,100
1968	1,436,000	30,000	393,000	217,000	113,390	2,189,390

that oil demand showed increases of a similar magnitude over the comparable period.

There are, however, other important factors, having an equal bearing on the size and composition of the motor vehicle population. The first of these is that about 90 per cent of all vehicles in the country are owned by Whites.¹⁹⁷ This implies that, whereas vehicle ownership amongst Whites may reach saturation level in the future, Non-White vehicle ownership should greatly increase with rising income levels.¹⁹⁷

Motor vehicle ownership amongst Whites in South Africa has in fact reached a very advanced stage, and is considered second only to the United States of America.¹⁹⁷

As the vehicle population of a country is normally studied in relation to the size of its population, it will be necessary to consider relevant population estimates for the Republic. In Table 33, estimates of the total population, broken down by race, are supplied for the Republic of South Africa over the period 1910 to 1968. Sources of data are the Jubilee Issue of Statistics (1960)⁴²⁷ and the various statistical Yearbooks⁷¹⁷ after 1960.

In order to facilitate comparisons with other countries in the world, it is necessary to combine the populations of motor-cars and commercial vehicles, as is shown in Table 34. The tractor and motor-cycle populations are normally not included in such an enumeration, but they are, nevertheless, important from the point of view of their fuel consumption.

Table 34 also shows that the total commercial vehicle population, as a percentage of the total motor-car population, has stabilised around

TABLE 33: REPUBLIC OF SOUTH AFRICA, MID-YEAR ESTIMATES OF THE TOTAL POPULATION,

1910 - 1968

('000)

YEAR	WHITES	COLOURED	ASIATICS	BANTU	TOTAL
	(1)	(2)	(3)	(4)	(5)
1910	1,257	517	148	3,956	5,878
1911	1,280	526	153	4,033	5,992
1912	1,305	530	154	4,114	6,103
1913	1,330	534	156	4,194	6,214
1914	1,355	538	157	4,275	6,325
1915	1,380	541	159	4,356	6,436
1916	1,405	545	161	4,436	6,547
1917	1,429	549	162	4,518	6,658
1918	1,454	553	164	4,598	6,769
1919	1,476	539	163	4,549	6,727
1920	1,500	542	164	4,631	6,837
1921	1,524	548	166	4,719	6,957
1922	1,550	563	170	4,845	7,128
1923	1,586	578	174	4,972	7,310
1924	1,620	593	177	5,099	7,489
1925	1,650	608	181	5,225	7,664
1926	1,682	623	184	5,352	7,841
1927	1,710	638	188	5,478	8,014
1928	1,741	653	191	5,605	8,190
1929	1,770	667	195	5,732	8,364
1930	1,801	682	199	5,858	8,540
1931	1,833	697	202	5,985	8,717
1932	1,868	713	206	6,111	8,898
1933	1,899	727	210	6,238	9,074
1934	1,934	742	213	6,365	9,254
1935	1,970	757	217	6,491	9,435
1936	2,009	772	221	6,616	9,618
1937	2,041	788	227	6,740	9,796
1938	2,085	804	234	6,863	9,986
1939	2,123	820	240	6,987	10,170
1940	2,160	836	247	7,110	10,353
1941	2,197	852	253	7,234	10,536
1942	2,231	868	260	7,357	10,716
1943	2,268	883	267	7,481	10,899
1944	2,305	899	273	7,604	11,081
1945	2,342	915	280	7,728	11,265
1946	2,380	932	286	7,851	11,449
1947	2,436	964	302	7,992	11,694
1948	2,504	999	318	8,136	11,957
1949	2,563	1,033	334	8,282	12,212
1950	2,608	1,069	351	8,432	12,460
1951	2,647	1,107	368	8,592	12,714
1952	2,693	1,146	379	8,822	13,040
1953	2,744	1,185	391	9,056	13,376
1954	2,791	1,226	404	9,296	13,717
1955	2,840	1,268	417	9,543	14,068
1956	2,885	1,310	429	9,797	14,421
1957	2,933	1,355	440	10,058	14,786
1958	2,983	1,401	452	10,324	15,160
1959	3,035	1,450	463	10,598	15,546
1960	3,069	1,500	476	10,880	15,925
1961	3,117	1,548	486	11,132	16,283
1962	3,170	1,596	498	11,387	16,651
1963	3,238	1,646	509	11,648	17,041
1964	3,323	1,699	520	11,915	17,457
1965	3,398	1,751	533	12,186	17,868
1966	3,481	1,805	547	12,465	18,298
1967	3,563	1,859	561	12,750	18,733
1968	3,639	1,912	574	13,042	19,167

TABLE 34: REPUBLIC OF SOUTH AFRICA, PER CAPITA VEHICLE OWNERSHIP, 1921 TO 1968

YEAR	MOTOR- CARS	COMMERCIAL VEHICLES (INCL. BUSES)	TOTAL	$\left[\frac{(2)}{(1)} \times 100 \right] \%$	PER CAPITA - '000 OF THE POPULATION		
					MOTOR- CARS	COMMERCIAL VEHICLES	TOTAL
	(1)	(2)	(3)=(1)+(2)	(4)	(5)	(6)	(7)
1921	25,521	1,264	26,785	5.0	4	-	4
1922	27,997	1,641	29,638	5.9	4	-	4
1923	34,014	1,983	35,997	5.8	5	-	5
1924	44,639	2,831	47,470	6.3	6	-	6
1925	56,668	4,036	60,704	7.1	7	1	8
1926	71,510	5,506	77,016	7.7	9	1	10
1927	87,830	7,972	95,802	9.1	11	1	12
1928	103,936	10,935	114,871	10.5	13	1	14
1929	120,829	14,047	134,876	11.6	14	2	16
1930	131,640	17,082	148,722	13.0	15	2	17
1931	135,258	18,878	154,136	14.0	16	2	18
1932	139,086	19,130	158,216	13.8	16	2	18
1933	146,490	19,466	165,956	13.3	16	2	18
1934	166,578	22,962	189,540	13.8	18	2	20
1935	195,483	28,257	223,740	14.5	21	3	24
1936	225,725	33,786	259,511	15.0	23	4	27
1937	259,330	40,660	299,990	15.7	26	4	30
1938	286,038	47,472	333,510	16.6	29	5	34
1939	303,211	52,591	355,802	17.3	30	5	35
1940	310,176	56,066	366,242	18.1	30	5	35
1941	310,823	59,464	370,287	19.1	30	6	36
1942	310,968	64,599	366,567	21.4	28	6	34
1943	286,626	67,206	353,832	23.4	26	6	32
1944	279,130	68,421	347,551	24.5	25	6	31
1945	276,606	70,950	347,556	25.7	25	6	31
1946	284,875	78,146	363,021	27.4	25	7	32
1947	314,900	89,895	404,795	28.5	27	8	35
1948	365,315	106,800	472,115	29.2	31	9	40
1949	410,759	121,725	532,484	29.6	34	10	44
1950	435,480	127,384	562,864	29.3	35	10	45
1951	451,595	131,528	583,123	29.1	36	10	46
1952	467,142	137,630	604,772	29.5	36	11	47
1953	487,053	143,850	630,903	29.5	36	11	47
1954	506,476	150,736	657,212	29.8	37	11	48
1955	528,234	161,679	689,913	30.6	38	11	49
1956	556,026	175,691	731,717	31.6	39	12	51
1957	600,465	189,183	789,648	31.5	41	13	54
1958	656,335	200,030	856,365	30.5	43	13	56
1959	705,755	207,924	913,679	29.5	45	13	58
1960	762,629	217,100	979,729	28.5	48	14	62
1961	803,305	223,711	1,027,016	27.8	49	14	63
1962	842,701	235,188	1,077,889	27.9	51	14	65
1963	923,178	255,554	1,178,732	27.7	54	15	69
1964	1,022,573	285,441	1,308,014	27.9	59	16	75
1965	1,125,100	317,570	1,442,670	28.2	63	18	81
1966	1,222,492	347,080	1,569,572	28.4	67	19	86
1967	1,323,000	374,000	1,697,000	28.3	71	20	91
1968	1,415,000	402,000	1,817,000	28.4	74	21	95

28 per cent in recent years, indicating an equal rate of expansion for both series. It also provides per capita data in respect of each type of vehicle.

2.4.6.1 Motor-cars

Table 34 shows that the motor-car population is by far the biggest single component in the total motor vehicle population. In 1964, South Africa ranked fifteenth in the world with 59 cars per thousand of the overall population.¹⁹⁷ For Whites alone, the relevant per capita statistics for cars were much higher in that year; about 281 motor cars per thousand Whites,¹⁹⁷ which illustrates afresh the high incidence of car ownership amongst the higher income groups.

The question is for how long per capita ownership for Whites will continue to increase at this high rate. According to Verburgh,⁷²⁷ saturation point will only be reached, in the case of the U.S.A., when a thousand persons are served by 450 motor cars; which means that most families will have two cars. If this is taken as a yardstick, it appears that the saturation point amongst Whites is still quite far off.

With further rapid economic growth and accompanying increased standards of living and higher purchasing power, it may well be expected that motor-car ownership will continue to show further steady rises.

2.4.6.2 Commercial vehicles

Commercial vehicles include trucks, lorries, pick-ups and other delivery vans. Buses are only special kinds of commercial vehicles and should, therefore, also be included under this heading.

The commercial vehicle population is relatively small in relation to the total, as rail transport is substantially protected in this

country. Long distance road transport is relatively undeveloped in South Africa, and is almost exclusively supplied by the Railways. In spite of this, the numbers of commercial vehicles have grown steadily in recent years, and in 1964, with 16 commercial vehicles per thousand of the population, South Africa ranked fifteenth in the world.¹⁹⁷

According to Verburgh,⁷²⁷ the future number of commercial vehicles will depend on the growth and structure of trade and industry, the extent of their markets, the location of establishments, public policy in respect to the licensing of vehicles, etc. As most of these factors are determined by growth in the economy generally, it is clear that, on the assumption of further economic growth, the numbers of commercial vehicles will continue to increase.

2.4.6.3 Tractors

Historical statistics on the tractor population, as provided by the various Motor Vehicle Reports, are extremely interrupted and incomplete. This is due to the fact that certain models of tractors are exempted from licensing in certain provinces, for certain periods.¹⁹⁷ About 80 per cent of the total tractor population is farm tractors, about which statistics are fortunately published fairly regularly in the various Agricultural Censuses.⁷³⁷ By using all possible sources in combination, it was possible to estimate the series on the total numbers of tractors in the Republic and South West Africa, as provided in the fourth column of Table 32.

The future number of agricultural tractors will largely be determined by the future size of the population, the output of the agricultural sector, the intensiveness to which available arable land is cultivated, and the degree of mechanisation in the agricultural sector. Most of these

factors can again be related back to economic growth, standards of living and disposable income, so that it may again be assumed that the number of tractors will show a steady increase in future, given steady future economic growth.

2.4.6.4 Motor-cycles

The motor-cycle population experienced a sudden explosive rate of increase over the period 1958 to 1965. This was due to the popularity of the so-called scooter and moped. Although their numbers are quite large, motor-cycles contribute very little to the total demand for oil for road transport purposes,¹⁹⁷ because of their small unit consumption.

CHAPTER 3

THE HISTORICAL ENERGY BALANCES OF SOUTH AFRICA

3.1 Introduction

In section 1.9.1.6 of Chapter 1 a method of analysing the energy economy was discussed, and intermediate balance sheets relating to each of the different stages of the analysis were constructed. Individual models were proposed for each of the stages of the analysis, including:

- availability of energy,
- production of primary energy,
- conversion of energy,
- final consumption of energy, and
- final consumption of useful energy.

Critical inspection of the statistical requirements for each of these models indicated that it would not be possible to construct these balances for South Africa in the manner indicated, as the data it calls for are not readily available. Statistical information, for all forms of energy, is not available on movements in stocks held at the various stages of the analysis, on own consumption in the production and conversion stages, or on the breakdown between the various forms of useful energy finally consumed. In the case of the own consumption of coal producers, for instance, it would not be correct to estimate own consumption by taking the difference between production and sales, as the excess, as is known, includes large quantities of low grade coal which are dumped and which are not used for purposes of own consumption by the mines. The only way to obtain the own consumption of coal producers would be to approach producers individually by means of surveys. Similarly, details on own consumption of forms of energy brought in from

outside producers and conversion installations are not available.

It is clear that much of the statistical requirements of the models outlined in section 1.9.1.6 can be obtained by means of surveys. Such an exercise would be so costly, however, in terms of time, money and labour, that it obviously falls outside the scope of this study. It is also clear that the models referred to were constructed predominantly to determine the efficiencies of production, conversion, and final consumption. That this is a vitally important aspect of the problem of analysing the energy economy hardly needs to be emphasised again, and indicates that a considerable amount of work still needs to be done in South Africa in this respect.

3.2 The integrated energy balance sheet

Given the limitation of inadequate statistical data, it will be necessary to approach the problem within the constraints set by available information. The lack of sufficiently detailed data has also been a limiting factor in other countries, and to overcome the obstacle an integrated energy balance has been proposed by Middelhoek²⁰⁷, incorporating most of the important principles set out in the method referred to in section 1.9.1.6

In addition to meeting the limitations set by lack of data, such an analysis must also be suitable for forecasting purposes. The models proposed by Middelhoek satisfy both these requirements very well and have, therefore, been selected as the basis for this study.

By means of this method, energy balances are constructed, integrating the intermediate balances for the stages of the analysis and the partial balances corresponding to each form of energy in their respective customary units, as illustrated by any one of the balances provided towards the end of

this Chapter.

At the top of the balance all energy-producing agents are classified according to four major homogeneous groups, i.e., electricity, gas, liquid fuels and solid fuels. Hydro and nuclear electricity, albeit historically unimportant or non-existent, are, nevertheless, indicated to illustrate its future inclusion.

On the left-hand side of the balance, as indicated, the demand for energy is divided into two major sectors, namely, demand at the final level and demand by the conversion sector. An energy demand model is, therefore, proposed which is divided into two major sector models. The model of final demand is again sub-divided into four sub-models, i.e., households, industry, mining and transport.

In the conversion model, the various producers of primary and secondary forms of energy are identified in the order listed at the top of the table. These include thermal, hydro and nuclear power stations, coal gas installations, producers of other gas, refineries, crude oil producers, mines, coke-ovens and gas-coke producers. In this classification, coal gas producers include all town gas producers (including Gascor). Other gas production includes all gas produced as a by-product, such as coke-oven gas and refinery gas. It is necessary, strictly speaking, to separate the Sasol oil-from-coal refinery from the conventional oil refineries. Because of lack of data on the operations of Sasol, such a separate classification for oil-from-coal refineries is not possible. Sasol is, therefore, included under the heading of refineries and is considered as a refinery using coal as source of raw material. As there is no other local production of crude petroleum, the row allocated for this purpose will always remain blank. Lastly, gas-coke produced as a by-product by town gas producers is identified separately, as shown on the balance (row 17).

By inserting the rows on import balances and production, the presentation assumes the form of an energy balance. The model must, therefore, be able to illustrate the development in the consumption in each of the blank spaces of the balance. In some instances, the balances show a number of blank spaces. This is caused by a lack of data on the consumption of forms of energy brought in from outside conversion installations. The information referred to is generally included in the industrial sub-model, so that the data on final consumption are relatively inflated. It can, however, safely be assumed that the error is small, in view of the relative insignificance of own consumption of the energy industries in relation to total demand.

3.3 A model of the conversion sector

The energy balance discussed in the previous section shows a marked resemblance to the traditional input-output table, with the exception that rows and columns are inverted. In the usual input-output table, outputs are read off horizontally and inputs vertically, while in the balance the presentation is reversed.

As in the case of the input-output table, the balance is further subdivided into two parts, i.e. in the establishment of final demand, which is derived by subtracting the import balance from inland final consumption of the particular energy-producing agent and the matrix of inputs within the energy sector itself.

Apart from these formal similarities, there is, however, one important aspect in which the balance differs from the input-output table and that is in respect of the treatment of imports of energy. In the usual input-output table imports are given in a separate column, so that inputs can be classified according to origin, whether imported or locally produced. In

the energy balance, however, imports are directly allocated to the various different energy-producing agents. As a corrective measure, imports, included in the import balance, need to be treated as a negative item in determining final demand.

This procedure makes it possible to derive the technical structure of consumption from the balance, which is not possible with the traditional input-output table. The input-coefficients, which can be constructed from the balance, therefore really represent the technical coefficients of production, given the state of technology in the year for which the balance was drawn up.

The technical coefficients are then defined in customary manner, i.e. as the quantity consumed of energy-producing agent i , required to produce 1 unit of energy-producing agent j , as indicated by the symbol a_{ij} .¹⁾

From the afore-mentioned, it may be concluded that the model, so constructed, could be described as an input-output model. If final demand of energy-source i is denoted by F_i and production by X_i , then the input-output model of the ten sectors indicated takes the form:

$$\begin{array}{ccccccc} X_1 & = & F_1 & + & a_{11} & X_1 & + & a_{12} & X_2 & + & \text{-----} & + & a_{1j} & X_j & + & \text{-----} & + & a_{1n} & X_n \\ | & & | & & | & & & | & & & & & | & & & & & | & \\ X_i & = & F_i & + & a_{i1} & X_1 & + & a_{i2} & X_2 & + & \text{-----} & + & a_{ij} & X_j & + & \text{-----} & + & a_{in} & X_n \\ | & & | & & | & & & | & & & & & | & & & & & | & \\ X_n & = & F_n & + & a_{n1} & X_1 & + & a_{n2} & X_2 & + & \text{-----} & + & a_{nj} & X_{nj} & + & \text{-----} & + & a_{nn} & X_n \end{array}$$

where $i, j = 1, \dots, n$ and $n = 10$

1) In deviating from the normal notation, i denotes columns and j denotes rows.

When F_i is assumed known, the system is reduced to ten equations and 10 unknowns, the latter being the production of each source of energy. The set of simultaneous equations can then be solved by successive elimination.

In matrix notation, the system can be described as:

$$\begin{aligned} X &= F + A' X \\ (I - A')X &= F \\ X &= (I - A')^{-1} F \end{aligned}$$

From the above, it follows, given the magnitude and composition of the final demand and the technical coefficients of transformation of the various sources of energy, that consumption by the conversion sectors, and, therefore, production of each source of energy, is fully determined.

3.4 A model of final demand

As was indicated in section 3.2, the model of final demand is divided into four sub-models, relating to demand in the domestic, industrial, mining and transport sectors.

The domestic sector includes energy consumed by households, small industrial concerns and the agricultural sector. Energy demands of commercial and industrial undertakings, including the iron and steel industry, are classified under the industrial sector. As was indicated before, this sector also includes nominal quantities of energy consumed in the conversion sector, being mostly sources of energy originating outside the installations consuming them. The energy demands of mines and associated activities are brought together in the mining sector. The demand for energy for road, air, rail or marine transport purposes, whether consumed in any of the afore-mentioned sectors or not, is included

in the transport sector.

Within each sub-model of final consumption, the analysis of energy consumption may be pursued in two ways, i.e.

- (i) by source of energy, separately, and by summation of all sources to establish total sectoral demand, and
- (ii) by consumption sector, analysing the sectoral total and its composition

Application of the first method may, however, yield inconsistencies in future estimates of energy demand if the model is extrapolated in forecasting, especially if significant substitution trends exist. These inconsistencies may apply to the total demand for energy, as well as between sources of energy. The second method overcomes these objections to a large extent as it considers the demand for a particular source of energy, having due regard for the demand for others at the same time. It will, however, be seen that the first method is quite useful under certain circumstances, particularly where it is used for control purposes.

In the sub-models of final consumption the demand for energy is generally analysed in two stages; analysis of the sectoral total and analysis of the contributions of each source of energy to the sectoral total. In doing so, two completely different aspects of the analysis of energy demand are separated. Another important advantage is that it facilitates a better treatment of the problem of substitution. Each sub-model, therefore, consists of a so-called sectoral relationship, describing the relationship between total energy demand and one or more activity indices or economic indicators, and, in addition, a number of relations describing the development of the pattern of demand. These relationships and their construction will be the subject of Chapter 5.

3.5 The historical energy balances for South Africa

The next few pages portray the development of the supply and demand for energy in South Africa since 1910. This effort must essentially be seen as the first step in this direction and it is by no means complete. A considerable amount of work still needs to be done, and the present attempt must be viewed within the limit set by availability of data.

The following paragraphs will consist mainly of a discussion of the sources of data from which the balances were built up. Most of the relevant statistics have already been discussed under the various sections dealing with the various energy industries.

3.5.1 Electricity

All the statistics provided in respect of the partial balance for electricity were obtained from official sources, and in particular, from the Jubilee Issue (1910 - 1960) of Statistics,^{42/} updated by the various Statistical Yearbooks,^{71/} and Quarterly Bulletins of Statistics,^{41/} after 1960.

Although data on the total generation of electricity in South Africa are available up to 1968, information on sales, or consumption by consumption sector, is only available up to 1964, as the relevant information can only be obtained from the various industrial censuses^{74/} conducted by the Department of Statistics. The required data from 1964 to 1968 were estimated fairly easily, as the relevant information for Escom is published in its Annual Reports.^{52/}

No significant quantities of electricity are as yet imported or exported and the excess of production over consumption naturally represents electricity consumed by power stations themselves, or lost.

ENERGY BALANCE

1968

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		6064			1536		7933		3494		17
2. INDUSTRY		14258			5937	69057	5542		6017	3929	50
3. MINING		11995					538		1505		
4. TRANSPORT		2070					31609		6459		
5. INLAND FINAL CONSUMPTION (1 - 4)		34387			7473	69057	45622	-	17475	3929	67
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	(4843)	54651	(1365)	-	-
7. FINAL DEMAND (5 - 6)		34387			7473	69057	50465	(54651)	18840	3929	67
8. THERMAL STATIONS		6561					167		28660		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					388		57		366		
12. OTHER GAS PRODUCTION						-					
13. REFINERIES							3187	56711	1970		
14. CRUDE PRODUCTION								-			
15. MINES									1234		
16. COKE PRODUCERS									5864	-	
17. GAS COKE PRODUCTION											40
18. PRODUCTION (7 - 17)		40948			7861	69057	53876	2060	56934	3929	107
19. TOTAL CONSUMPTION (6 + 18)		40948			7861	69057	49033	56711	55569	3929	107

ENERGY BALANCE

1967

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		5667			1657		7680		3623		19
2. INDUSTRY		12730			3458	62990	4886		5161	3731	61
3. MINING		11441					499		1448		
4. TRANSPORT		1897					29035		6395		
5. INLAND FINAL CONSUMPTION (1 - 4)		31735			5115	62990	42100	-	16627	3731	80
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	(5687)	73278	(1381)	-	-
7. FINAL DEMAND (5 - 6)		31735			5115	62990	47787	(73278)	18008	3731	80
8. THERMAL STATIONS		6134					251		27525		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					337		29		275		
12. OTHER GAS PRODUCTION											
13. REFINERIES							2553	75259	1894		
14. CRUDE PRODUCTION											
15. MINES									1147		
16. COKE PRODUCERS									5569		
17. GAS COKE PRODUCTION											41
18. PRODUCTION (7 - 17)		37869			5452	62990	50620	1981	54418	3731	121
19. TOTAL CONSUMPTION (6 + 18)		37869			5452	62990	44933	75259	53037	3731	121

ENERGY BALANCE

1966

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		5087			1856		7327		3670		15
2. INDUSTRY		11598			1532	59400	4059		5626	3618	55
3. MINING		10775					467		1507		
4. TRANSPORT		1799					26944		6873		
5. INLAND FINAL CONSUMPTION (1 - 4)		29259			3388	59400	38797	-	17676	3618	70
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	3719	40160	(1197)	-	-
7. FINAL DEMAND (5 - 6)		29259			3388	59400	35078	(40160)	18873	3618	70
8. THERMAL STATIONS		5500					275		25352		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					312				209		
12. OTHER GAS PRODUCTION											
13. REFINERIES							2914	42134	1888		
14. CRUDE PRODUCTION											
15. MINES									1161		
16. COKE PRODUCERS									5400		
17. GAS COKE PRODUCTION											50
18. PRODUCTION (7 - 17)		34759			3700	59400	38267	1974	52883	3618	120
19. TOTAL CONSUMPTION (6 + 18)		34759			3700	59400	41986	42134	51686	3618	120

ENERGY BALANCE

1965

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		4859			1873		7226		3950		14
2. INDUSTRY		10760			1245	57970	3011		6779	3531	54
3. MINING		10271					437		1440		
4. TRANSPORT		1661					24462		7402		
5. INLAND FINAL CONSUMPTION (1 - 4)		27551			3118	57970	35136	=	19571	3531	68
6. IMPORT BALANCE INCL. BUNKERS		=			=	=	5005	37530	(1417)	=	=
7. FINAL DEMAND (5 - 6)		27551			3118	57970	30131	(37530)	20988	3531	68
8. THERMAL STATIONS		5221					511		24328		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					304				172		
12. OTHER GAS PRODUCTION											
13. REFINERIES							2101	39301	1694		
14. CRUDE PRODUCTION											
15. MINES									966		
16. COKE PRODUCERS									5270		
17. GAS COKE PRODUCTION											43
18. PRODUCTION (7 - 17)		32772			3422	57970	32743	1771	53418	3531	111
19. TOTAL CONSUMPTION (6 + 18)		32772			3422	57970	37748	39301	52001	3531	111

ENERGY BALANCE

1964

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		4499			1850		6870		3410		15
2. INDUSTRY		9580			1160	48730	2351		6456	2968	54
3. MINING		9758					409		1780		
4. TRANSPORT		1420					22085		6846		
5. INLAND FINAL CONSUMPTION (1 - 4)		25257			3010	48730	31715	-	18492	2968	69
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	1190	35733	(1418)	-	-
7. FINAL DEMAND (5 - 6)		25257			3010	48730	30525	(35733)	19910	2968	69
8. THERMAL STATIONS		5165					305		22477		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					300				174		
12. OTHER GAS PRODUCTION											
13. REFINERIES							3399	37439	1631		
14. CRUDE PRODUCTION											
15. MINES									891		
16. COKE PRODUCERS									4430		
17. GAS COKE PRODUCTION											43
18. PRODUCTION (7 - 17)		30422			3310	48730	34229	1706	49513	2968	112
19. TOTAL CONSUMPTION (6 + 18)		30422			3310	48730	35419	37439	48095	2968	112

ENERGY BALANCE

1963

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		4152			1828		6622		3250		18
2. INDUSTRY		8693			1079	44550	1924		5529	2714	62
3. MINING		9524					383		1950		
4. TRANSPORT		1337					19977		6906		
5. INLAND FINAL CONSUMPTION (1 - 4)		23706			2907	44550	28906	-	17635	2714	80
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	13361	15869	(1485)	-	-
7. FINAL DEMAND (5 - 6)		23706			2907	44550	15545	(15869)	19120	2714	80
8. THERMAL STATIONS		5122					204		21330		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					230				189		
12. OTHER GAS PRODUCTION											
13. REFINERIES							615	17386	1451		
14. CRUDE PRODUCTION											
15. MINES									658		
16. COKE PRODUCERS									4050		
17. GAS COKE PRODUCTION											45
18. PRODUCTION (7 - 17)		28828			3137	44550	16364	1517	46798	2714	125
19. TOTAL CONSUMPTION (6 + 18)		28828			3137	44550	29725	17386	45313	2714	125

ENERGY BALANCE

1962

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		3951			1687		6275		2990		12
2. INDUSTRY		7770			1030	43780	1449		6056	2667	46
3. MINING		9121					359		1340		
4. TRANSPORT		1224					18673		6950		
5. INLAND FINAL CONSUMPTION (1 - 4)		22066			2717	43780	26756	-	17336	2667	58
6. IMPORT BALANCE INCL. BUNKERS		-				-	16408	12086	(1749)	-	-
7. FINAL DEMAND (5 - 6)		22066			2717	43780	10348	(12086)	19085	2667	58
8. THERMAL STATIONS		4039					387		20448		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					270				179		
12. OTHER GAS PRODUCTION											
13. REFINERIES							1388	13673	1518		
14. CRUDE PRODUCTION											
15. MINES									288		
16. COKE PRODUCERS									3980		
17. GAS COKE PRODUCTION											41
18. PRODUCTION (7 - 17)		26105			2987	43780	12123	1587	45498	2667	99
19. TOTAL CONSUMPTION (6 + 18)		26105			2987	43780	28531	13673	43749	2667	99

ENERGY BALANCE

1961

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		4051			1699		6109		3120		11
2. INDUSTRY		7044			1040	41580	1180		5397	2533	43
3. MINING		8796					336		1540		
4. TRANSPORT		1077					17852		6899		
5. INLAND FINAL CONSUMPTION (1 - 4)		20968			2739	41580	25477	-	16956	2533	54
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	15576	11083	(1164)	-	-
7. FINAL DEMAND (5 - 6)		20968			2739	41580	9901	(11083)	18120	2533	54
8. THERMAL STATIONS		3588					358		18850		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					282				152		
12. OTHER GAS PRODUCTION											
13. REFINERIES							769	12611	1461		
14. CRUDE PRODUCTION											
15. MINES									1250		
16. COKE PRODUCERS									3780		
17. GAS COKE PRODUCTION											35
18. PRODUCTION (7 - 17)		24556			3021	41580	11028	1528	43613	2533	89
19. TOTAL CONSUMPTION (6 + 18)		24556			3021	41580	26604	12611	42449	2533	89

ENERGY BALANCE

1960

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		3793			1761		5857		3210		13
2. INDUSTRY		6342			1030	39710	987		5725	2419	48
3. MINING		8237					315		1520		
4. TRANSPORT		962					17097		7239		
5. INLAND FINAL CONSUMPTION (1 - 4)		19334			2791	39710	24256	-	17694	2419	61
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	14900	9580	(1048)	-	-
7. FINAL DEMAND (5 - 6)		19334			2791	39710	9356	(9580)	18742	2419	61
8. THERMAL STATIONS		3227					510		18124		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					289				159		
12. OTHER GAS PRODUCTION											
13. REFINERIES							(1221)	10968	1327		
14. CRUDE PRODUCTION											
15. MINES									117		
16. COKE PRODUCERS									3610		
17. GAS COKE PRODUCTION											40
18. PRODUCTION (7 - 17)		22561			3080	39710	8645	1388	42079	2419	101
19. TOTAL CONSUMPTION (6 + 18)		22561			3080	39710	23545	10968	41031	2419	101

ENERGY BALANCE

1959

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS		3556			1715		5601		3270		15
2. INDUSTRY		5952			963	38060	940		4525	2318	51
3. MINING		7765					296		1560		
4. TRANSPORT		859					16184		7356		
5. INLAND FINAL CONSUMPTION (1 - 4)		18132			2678	38060	23021	-	16711	2318	66
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	13808	9630	(536)	-	-
7. FINAL DEMAND (5 - 6)		18132			2678	38060	9213	(9630)	17247	2318	66
8. THERMAL STATIONS		3033					469		17041		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					277				155		
12. OTHER GAS PRODUCTION											
13. REFINERIES							(916)	10979	1290		
14. CRUDE PRODUCTION											
15. MINES									989		
16. COKE PRODUCERS									3460		
17. GAS COKE PRODUCTION											32
18. PRODUCTION (7 - 17)		21165			2955	38060	8766	1349	40182	2318	98
19. TOTAL CONSUMPTION (6 + 18)		21165			2955	38060	22574	10979	39646	2318	98

ENERGY BALANCE

1958

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		3360			1709		5330		3050		14
2. INDUSTRY		5623			916	32230	884		5355	1963	53
3. MINING		7510					278		2223		
4. TRANSPORT		828					15533		8141		
5. INLAND FINAL CONSUMPTION (1 - 4)		17321			2625	32230	22025	-	18769	1963	67
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	14178	9670	(676)	-	-
7. FINAL DEMAND (5 - 6)		17321			2625	32230	7847	(9670)	19445	1963	67
8. THERMAL STATIONS		2812					628		16217		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					271				166		
12. OTHER GAS PRODUCTION											
13. REFINERIES							468	10906	1182		
14. CRUDE PRODUCTION											
15. MINES									939		
16. COKE PRODUCERS									2930		
17. GAS COKE PRODUCTION											43
18. PRODUCTION (7 - 17)		20133			2896	32230	8943	1236	40879	1963	110
19. TOTAL CONSUMPTION (.6 + 18)		20133			2896	32230	23121	10906	40203	1963	110

ENERGY BALANCE

1957

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		3385			1666		5159		3060		15
2. INDUSTRY		5437			814	30910	770		5441	1883	52
3. MINING		7493					261		1530		
4. TRANSPORT		825					14285		7690		
5. INLAND FINAL CONSUMPTION (1 - 4)		17140			2480	30910	20475	-	17721	1883	67
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	12996	7972	(646)	-	-
7. FINAL DEMAND (5 - 6)		17140			2480	30910	7479	(7972)	18367	1883	67
8. THERMAL STATIONS		2814					847		15249		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					261				170		
12. OTHER GAS PRODUCTION											
13. REFINERIES							(745)	9113	1091		
14. CRUDE PRODUCTION											
15. MINES									639		
16. COKE PRODUCERS									2810		
17. GAS COKE PRODUCTION											40
18. PRODUCTION (7 - 17)		19954			2741	30910	7581	1141	38326	1883	107
19. TOTAL CONSUMPTION (6 + 18)		19954			2741	30910	20577	9113	37680	1883	107

ENERGY BALANCE

1956

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		2973			1663		4948		3120		14
2. INDUSTRY		4852			815	29810	651		4832	1816	52
3. MINING		7168					246		1580		
4. TRANSPORT		789					13210		7052		
5. INLAND FINAL CONSUMPTION (1 - 4)		15782			2478	29810	19055	-	16584	1816	66
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	14793	7268	(678)	-	-
7. FINAL DEMAND (5 - 6)		15782			2478	29810	4262	(7268)	17262	1816	66
8. THERMAL STATIONS		2753					1102		14607		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					266				158		
12. OTHER GAS PRODUCTION											
13. REFINERIES							1601	8139	833		
14. CRUDE PRODUCTION											
15. MINES									1470		
16. COKE PRODUCERS									2710		
17. GAS COKE PRODUCTION											43
18. PRODUCTION (7 - 17)		18535			2744	29810	6965	871	37040	1816	109
19. TOTAL CONSUMPTION (6 + 18)		18535			2744	29810	21758	8139	36362	1816	109

ENERGY BALANCE

1955

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		2674			1650		4700		3160		15
2. INDUSTRY		4503			776	27610	610		3912	1682	53
3. MINING		6397					231		1650		
4. TRANSPORT		736					12418		6812		
5. INLAND FINAL CONSUMPTION (1 - 4)		14310			2426	27610	17959	-	15534	1682	68
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	12907	7055	(666)	-	-
7. FINAL DEMAND (5 - 6)		14310			2426	27610	5052	(7055)	16200	1682	68
8. THERMAL STATIONS		2862					987		13599		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					261				158		
12. OTHER GAS PRODUCTION											
13. REFINERIES							315	7676	594		
14. CRUDE PRODUCTION											
15. MINES									2335		
16. COKE PRODUCERS									2510		
17. GAS COKE PRODUCTION											42
18. PRODUCTION (7 - 17)		17172			2687	27610	6354	621	35396	1682	110
19. TOTAL CONSUMPTION (6 + 18)		17172			2687	27610	19261	7676	34730	1682	110

ENERGY BALANCE

1954

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		2474			1588		4521		2940		17
2. INDUSTRY		3890			720	27610	575		3501	1682	53
3. MINING		5754					217		1540		
4. TRANSPORT		694					11513		6575		
5. INLAND FINAL CONSUMPTION (1 - 4)		12812			2308	27610	16826	-	14556	1682	70
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	12933	5412	(1317)	-	-
7. FINAL DEMAND (5 - 6)		12812			2308	27610	3893	(5412)	15873	1682	70
8. THERMAL STATIONS		2372					814		12255		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					244				156		
12. OTHER GAS PRODUCTION											
13. REFINERIES							(21)	5464	50		
14. CRUDE PRODUCTION											
15. MINES									1469		
16. COKE PRODUCERS									2510		
17. GAS COKE PRODUCTION											43
18. PRODUCTION (7 - 17)		15184			2552	27610	4686	52	32313	1682	113
19. TOTAL CONSUMPTION (6 + 18)		15184			2552	27610	17619	5464	30996	1682	113

ENERGY BALANCE

1953

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		2265			1548		4100		3160		16
2. INDUSTRY		3444			657	24431	524		4257	1488	52
3. MINING		5257					204		1560		
4. TRANSPORT		840					11036		6359		
5. INLAND FINAL CONSUMPTION (1 - 4)		11806			2205	24431	15864	-	15336	1488	68
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	15882	202	(1381)	-	-
7. FINAL DEMAND (5 - 6)		11806			2205	24431	(18)	(202)	16717	1488	68
8. THERMAL STATIONS		1938					633		11480		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					236				152		
12. OTHER GAS PRODUCTION											
13. REFINERIES							(333)				
14. CRUDE PRODUCTION											
15. MINES									801		
16. COKE PRODUCERS									2221		
17. GAS COKE PRODUCTION											43
18. PRODUCTION (7 - 17)		13744			2441	24431	282		31371	1488	111
19. TOTAL CONSUMPTION (6 + 18)		13744			2441	24431	16164		29990	1488	111

ENERGY BALANCE

1952

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		2030			1538		3638		3300		18
2. INDUSTRY		3323			675	23441	469		4666	1428	58
3. MINING		5091					192		1610		
4. TRANSPORT		790					10573		6327		
5. INLAND FINAL CONSUMPTION (1 - 4)		11234			2213	23441	14872		15903	1428	76
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	15725		(1011)	-	-
7. FINAL DEMAND (5 - 6)		11234			2213	23441	(853)		16914	1428	76
8. THERMAL STATIONS		1283					574		10849		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					241				144		
12. OTHER GAS PRODUCTION											
13. REFINERIES							528				
14. CRUDE PRODUCTION											
15. MINES									898		
16. COKE PRODUCERS									2131		
17. GAS COKE PRODUCTION											35
18. PRODUCTION (7 - 17)		12517			2454	23441	249		30936	1428	111
19. TOTAL CONSUMPTION (6 + 18)		12517			2454	23441	15974		29925	1428	111

ENERGY BALANCE

1951

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		1873			1449		3372		3133		13
2. INDUSTRY		2995			640	22792	460		3422	1388	47
3. MINING		4831					181		1919		
4. TRANSPORT		775					10160		5880		
5. INLAND FINAL CONSUMPTION (1 - 4)		10474			2089	22792	14173		14354	1388	60
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	14877		(2106)	-	-
7. FINAL DEMAND (5 - 6)		10474			2089	22792	(704)		16460	1388	60
8. THERMAL STATIONS		1421					633		10103		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					233				133		
12. OTHER GAS PRODUCTION											
13. REFINERIES							320				
14. CRUDE PRODUCTION											
15. MINES									589		
16. COKE PRODUCERS									2072		
17. GAS COKE PRODUCTION											40
18. PRODUCTION (7 - 17)		11895			2322	22792	249		29357	1388	100
19. TOTAL CONSUMPTION (6 + 18)		11895			2322	22792	15126		27251	1388	100

ENERGY BALANCE

1950

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		1659			1403		2803		3042		12
2. INDUSTRY		2818			594	19525	399		3185	1189	43
3. MINING		4676					171		2226		
4. TRANSPORT		597					9402		5584		
5. INLAND FINAL CONSUMPTION (1 - 4)		9750			1997	19525	12775		14037	1189	55
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	13238		(3205)	-	-
7. FINAL DEMAND (5 - 6)		9750			1997	19525	(463)		17242	1189	55
8. THERMAL STATIONS		1437					629		9514		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					220				134		
12. OTHER GAS PRODUCTION											
13. REFINERIES							103				
14. CRUDE PRODUCTION											
15. MINES									517		
16. COKE PRODUCERS									1775		
17. GAS COKE PRODUCTION											37
18. PRODUCTION (7 - 17)		11187			2217	19525	269		29182	1189	92
19. TOTAL CONSUMPTION (6 + 18)		11187			2217	19525	13507		25977	1189	92

ENERGY BALANCE

1949

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		1462			1427		2545		2953		12
2. INDUSTRY		2471			593	18590	328		3213	1132	43
3. MINING		4303					135		2533		
4. TRANSPORT		593					9251		5563		
5. INLAND FINAL CONSUMPTION (1 - 4)		8829			2020	18590	12259		14262	1132	55
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	12823		(2620)	-	-
7. FINAL DEMAND (5 - 6)		8829			2020	18590	(564)		16882	1132	55
8. THERMAL STATIONS		1184					687		8721		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					223				134		
12. OTHER GAS PRODUCTION											
13. REFINERIES							137				
14. CRUDE PRODUCTION											
15. MINES									678		
16. COKE PRODUCERS									1690		
17. GAS COKE PRODUCTION											38
18. PRODUCTION (7 - 17)		10013			2243	18590	260		28105	1132	93
19. TOTAL CONSUMPTION (6 + 18)		10013			2243	18590	13083		25485	1132	93

ENERGY BALANCE

1948

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		1343			1390		2111		2867		10
2. INDUSTRY		2207			565	15466	272	.	2386	942	39
3. MINING		4002					95		2838		
4. TRANSPORT		537					8240		5629		
5. INLAND FINAL CONSUMPTION (1 - 4)		8089			1955	15466	10718		13720	942	49
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	11700		(2455)	-	-
7. FINAL DEMAND (5 - 6)		8089			1955	15466	(982)		16175	942	49
8. THERMAL STATIONS		1392					655		8270		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					217				117		
12. OTHER GAS PRODUCTION											
13. REFINERIES							565				
14. CRUDE PRODUCTION											
15. MINES									514		
16. COKE PRODUCERS									1406		
17. GAS COKE PRODUCTION											31
18. PRODUCTION (7 - 17)		9481			2172	15466	238		26482	942	80
19. TOTAL CONSUMPTION (6 + 18)		9481			2172	15466	11938		24027	942	80

ENERGY BALANCE

1947

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		1206			1312		1802		2600		9
2. INDUSTRY		1994			524	14377	187		1755	876	37
3. MINING		3782					55		2468		
4. TRANSPORT		512					7043		5444		
5. INLAND FINAL CONSUMPTION (1 - 4)		7494			1836	14377	9087		12267	876	46
6. IMPORT BALANCE INCL. BURNERS		-			-	-	9036		(3529)	-	-
7. FINAL DEMAND (5 - 6)		7494			1836	14377	51		15769	876	46
8. THERMAL STATIONS		1294					592		8203		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					205				109		
12. OTHER GAS PRODUCTION											
13. REFINERIES							(441)				
14. CRUDE PRODUCTION											
15. MINES									487		
16. COKE PRODUCERS									1307		
17. GAS COKE PRODUCTION											29
18. PRODUCTION (7 - 17)		8788			2041	14377	202		25902	876	75
19. TOTAL CONSUMPTION (6 + 18)		8788			2041	14377	9238		22373	876	75

ENERGY BALANCE

1946

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		1089			1182		1576		2518		9
2. INDUSTRY		1939			452	13475	115		2261	821	35
3. MINING		3797					25		2898		
4. TRANSPORT		513					5780		5152		
5. INLAND FINAL CONSUMPTION (1 - 4)		7338			1634	13475	7496		12829	821	44
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	8801		(4249)	-	-
7. FINAL DEMAND (5 - 6)		7338			1634	13475	(1305)		17078	821	44
8. THERMAL STATIONS		1219					549		7225		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					181				106		
12. OTHER GAS PRODUCTION											
13. REFINERIES							1026				
14. CRUDE PRODUCTION											
15. MINES									383		
16. COKE PRODUCERS									1225		
17. GAS COKE PRODUCTION											29
18. PRODUCTION (7 - 17)		8557			1815	13475	270		26017	821	73
19. TOTAL CONSUMPTION (6 + 18)		8557			1815	13475	9071		21768	821	73

ENERGY BALANCE

1945

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		991			1122		1285		2445		8
2. INDUSTRY		1887			429	13255	99		1987	807	34
3. MINING		3777					14		2497		
4. TRANSPORT		487					4231		5012		
5. INLAND FINAL CONSUMPTION (1 - 4)		7142			1561	13255	5629		11941	807	42
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	7060		(5016)	-	-
7. FINAL DEMAND (5 - 6)		7142			1561	13255	(1431)		16957	807	42
8. THERMAL STATIONS		1187					520		7202		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					175				102		
12. OTHER GAS PRODUCTION											
13. REFINERIES							1156				
14. CRUDE PRODUCTION											
15. MINES									498		
16. COKE PRODUCERS									1205		
17. GAS COKE PRODUCTION											28
18. PRODUCTION (7 - 17)		8329			1736	13255	245		25964	807	70
19. TOTAL CONSUMPTION (6 + 18)		8329			1736	13255	7305		20948	807	70

ENERGY BALANCE

1944

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		936			1091		1163		2548		8
2. INDUSTRY		1781			407	12782	95		2069	779	32
3. MINING		3714					13		2445		
4. TRANSPORT		489					4357		4716		
5. INLAND FINAL CONSUMPTION (1 - 4)		6920			1498	12782	5628		11778	779	40
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	7015		(4895)	-	-
7. FINAL DEMAND (5 - 6)		6920			1498	12782	(1387)		16673	779	40
8. THERMAL STATIONS		1123					509		6977		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					172				95		
12. OTHER GAS PRODUCTION											
13. REFINERIES							1123				
14. CRUDE PRODUCTION											
15. MINES									432		
16. COKE PRODUCERS									1162		
17. GAS COKE PRODUCTION											25
18. PRODUCTION (7 - 17)		8043			1670	12782	245		25339	779	65
19. TOTAL CONSUMPTION (6 + 18)		8043			1670	12782	7260		20444	779	65

ENERGY BALANCE

1943

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		887			1026		1033		2474		8
2. INDUSTRY		1626			371	12496	87		1876	761	32
3. MINING		3648					12		2378		
4. TRANSPORT		477					4339		4545		
5. INLAND FINAL CONSUMPTION (1 - 4)		6638			1397	12496	5471		11273	761	40
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	11441		(3093)	-	-
7. FINAL DEMAND (5 - 6)		6638			1397	12496	(5970)		14366	761	40
8. THERMAL STATIONS		1062					480		6691		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					161				94		
12. OTHER GAS PRODUCTION											
13. REFINERIES							5733				
14. CRUDE PRODUCTION											
15. MINES									377		
16. COKE PRODUCERS									1136		
17. GAS COKE PRODUCTION											25
18. PRODUCTION (7 - 17)		7700			1558	12496	243		22664	761	65
19. TOTAL CONSUMPTION (6 + 18)		7700			1558	12496	11684		19571	761	65

ENERGY BALANCE

1942

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		863			853		1257		2365		7
2. INDUSTRY		1599			305	12386	87		1513	754	28
3. MINING		3830					11		2443		
4. TRANSPORT		476					4707		4449		
5. INLAND FINAL CONSUMPTION (1 - 4)		6768			1158	12386	6062		10770	754	35
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	16329		(3295)	-	-
7. FINAL DEMAND (5 - 6)		6768			1158	12386	(10267)		14065	754	35
8. THERMAL STATIONS		1031					492		6824		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					136				87		
12. OTHER GAS PRODUCTION											
13. REFINERIES							10018				
14. CRUDE PRODUCTION											
15. MINES									394		
16. COKE PRODUCERS									1126		
17. GAS COKE PRODUCTION											25
18. PRODUCTION (7 - 17)		7799			1294	12386	243		22496	754	60
19. TOTAL CONSUMPTION (6 + 18)		7799			1294	12386	16572		19201	754	60

ENERGY BALANCE

1941

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		812			834		906		2250		7
2. INDUSTRY		1475			281	8932	84		1123	544	26
3. MINING		3750					11		2453		
4. TRANSPORT		468					5307		4258		
5. INLAND FINAL CONSUMPTION (1 - 4)		6505			1115	8932	6308		10084	544	33
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	13631		(2723)	-	-
7. FINAL DEMAND (5 - 6)		6505			1115	8932	(7323)		12807	544	33
8. THERMAL STATIONS		1087					471		6516		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					130				78		
12. OTHER GAS PRODUCTION											
13. REFINERIES							7095				
14. CRUDE PRODUCTION											
15. MINES									377		
16. COKE PRODUCERS									812		
17. GAS COKE PRODUCTION											20
18. PRODUCTION (7 - 17)		7592			1245	8932	243		20590	544	53
19. TOTAL CONSUMPTION (6 + 18)		7592			1245	8932	13874		17867	544	53

ENERGY BALANCE

1940

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		758			784		795		2145		6
2. INDUSTRY		1333			273	7744	83		1003	472	25
3. MINING		3587					11		2414		
4. TRANSPORT		444					5129		4108		
5. INLAND FINAL CONSUMPTION (1 - 4)		6122			1057	7744	6018		9670	472	31
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	14861		(2378)	-	-
7. FINAL DEMAND (5 - 6)		6122			1057	7744	(8843)		12048	472	31
8. THERMAL STATIONS		1046					446		6108		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					121				74		
12. OTHER GAS PRODUCTION											
13. REFINERIES							8640				
14. CRUDE PRODUCTION											
15. MINES									349		
16. COKE PRODUCERS									704		
17. GAS COKE PRODUCTION											21
18. PRODUCTION (7 - 17)		7168			1178	7744	243		19283	472	52
19. TOTAL CONSUMPTION (6 + 18)		7168			1178	7744	15104		16905	472	52

ENERGY BALANCE

1939

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		686			709		883		2035		6
2. INDUSTRY		1147			254	8008	100		1056	488	24
3. MINING		3201					11		2384		
4. TRANSPORT		419					5138		3888		
5. INLAND FINAL CONSUMPTION (1 - 4)		5453			963	8008	6132		9363	488	30
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	9893		(2152)	-	-
7. FINAL DEMAND (5 - 6)		5453			963	8008	(3761)		11515	488	30
8. THERMAL STATIONS		1121					463		5791		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					111				72		
12. OTHER GAS PRODUCTION											
13. REFINERIES							3541				
14. CRUDE PRODUCTION											
15. MINES									512		
16. COKE PRODUCERS									728		
17. GAS COKE PRODUCTION											19
18. PRODUCTION (7 - 17)		6574			1074	8008	243		18618	488	49
19. TOTAL CONSUMPTION (6 + 18)		6574			1074	8008	10136		16466	488	49

ENERGY BALANCE

1938

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		610			632		639		2135		5
2. INDUSTRY		1060			244	7392	98		1025	450	23
3. MINING		2873					10		2441		
4. TRANSPORT		355					4807		3612		
5. INLAND FINAL CONSUMPTION (1 - 4)		4898			876	7392	5554		9213	450	28
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	8022		(2225)	-	-
7. FINAL DEMAND (5 - 6)		4898			876	7392	(2468)		11438	450	28
8. THERMAL STATIONS		1035					412		5358		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					104				68		
12. OTHER GAS PRODUCTION											
13. REFINERIES							2290				
14. CRUDE PRODUCTION											
15. MINES									414		
16. COKE PRODUCERS									672		
17. GAS COKE PRODUCTION											19
18. PRODUCTION (7 - 17)		5933			980	7392	234		17950	450	47
19. TOTAL CONSUMPTION (6 + 18)		5933			980	7392	8256		15725	450	47

ENERGY BALANCE

1937

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		520			581		629		2020		5
2. INDUSTRY		966			240	5940	115		759	362	22
3. MINING		2602					8		2278		
4. TRANSPORT		273					4261		4065		
5. INLAND FINAL CONSUMPTION (1 - 4)		4361			821	5940	5013		9122	362	27
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	7179		(2122)	-	-
7. FINAL DEMAND (5 - 6)		4361			821	5940	(2166)		11244	362	27
8. THERMAL STATIONS		975					390		4872		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					100				62		
12. OTHER GAS PRODUCTION											
13. REFINERIES							2002				
14. CRUDE PRODUCTION											
15. MINES									358		
16. COKE PRODUCERS									540		
17. GAS COKE PRODUCTION											16
18. PRODUCTION (7 - 17)		5336			921	5940	226		17076	362	43
19. TOTAL CONSUMPTION (6 + 18)		5336			921	5940	7405		14954	362	43

ENERGY BALANCE

1936

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		389			485		557		1900		4
2. INDUSTRY		860			221	4950	117		775	302	19
3. MINING		2288					6		2250		
4. TRANSPORT		231					3442		3581		
5. INLAND FINAL CONSUMPTION (1 - 4)		3768			706	4950	4122		8506	302	23
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	5632		(2518)	-	-
7. FINAL DEMAND (5 - 6)		3768			706	4950	(1510)		11024	302	23
8. THERMAL STATIONS		835					367		4482		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					90				40		
12. OTHER GAS PRODUCTION											
13. REFINERIES							1360				
14. CRUDE PRODUCTION											
15. MINES									364		
16. COKE PRODUCERS									450		
17. GAS COKE PRODUCTION											14
18. PRODUCTION (7 - 17)		4603			796	4950	217		16360	302	37
19. TOTAL CONSUMPTION (6 + 18)		4603			796	4950	5849		13842	302	37

ENERGY BALANCE

1935

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		370			387		483		1789		2
2. INDUSTRY		639			203	4400	123		580	268	17
3. MINING		2018					2		2109		
4. TRANSPORT		219					2800		3336		
5. INLAND FINAL CONSUMPTION (1 - 4)		3246			590	4400	3408		7814	268	19
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	4425		(2446)	-	-
7. FINAL DEMAND (5 - 6)		3246			590	4400	(1017)		10260	268	19
8. THERMAL STATIONS		527					342		3920		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					79				28		
12. OTHER GAS PRODUCTION											
13. REFINERIES							884				
14. CRUDE PRODUCTION											
15. MINES									355		
16. COKE PRODUCERS									400		
17. GAS COKE PRODUCTION											12
18. PRODUCTION (7 - 17)		3773			669	4400	209		14963	268	31
19. TOTAL CONSUMPTION (6 + 18)		3773			669	4400	4634		12517	268	31

ENERGY BALANCE

1934

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		308			320		577		1669		2
2. INDUSTRY		577			188	2750	122		591	235	16
3. MINING		1780					-		1996		
4. TRANSPORT		189					2372		2991		
5. INLAND FINAL CONSUMPTION (1 - 4)		2854			508	2750	3071		7247	235	18
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	3736		(2031)	-	-
7. FINAL DEMAND (5 - 6)		2854			508	2750	(665)		9278	235	18
8. THERMAL STATIONS		455					317		3469		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					72				20		
12. OTHER GAS PRODUCTION											
13. REFINERIES							548				
14. CRUDE PRODUCTION											
15. MINES									325		
16. COKE PRODUCERS									350		
17. GAS COKE PRODUCTION											10
18. PRODUCTION (7 - 17)		3309			580	2750	200		13442	235	28
19. TOTAL CONSUMPTION (6 + 18)		3309			580	2750	3936		11411	235	28

ENERGY BALANCE

1933

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		254			282		405		1549		2
2. INDUSTRY		456			188	2200	117		250	134	14
3. MINING		1591					-		1847		
4. TRANSPORT		161					2055		2832		
5. INLAND FINAL CONSUMPTION (1 - 4)		2462			470	2200	2577		6478	134	16
6. IMPORT BALANCE INCL. BUNKERS		-			-	-	3063		(1791)	-	-
7. FINAL DEMAND (5 - 6)		2462			470	2200	(486)		8269	134	16
8. THERMAL STATIONS		485					293		3041		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS					70				18		
12. OTHER GAS PRODUCTION											
13. REFINERIES							384				
14. CRUDE PRODUCTION											
15. MINES									283		
16. COKE PRODUCERS									200		
17. GAS COKE PRODUCTION											11
18. PRODUCTION (7 - 17)		2947			540	2200	191		11811	134	27
19. TOTAL CONSUMPTION (6 + 18)		2947			540	2200	3254		10020	134	27

ENERGY BALANCE

1932

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS							371		1609		
2. INDUSTRY							113		260		
3. MINING							-		1842		
4. TRANSPORT							1817		2463		
5. INLAND FINAL CONSUMPTION (1 - 4)		N/A					2301		6174		
6. IMPORT BALANCE INCL. BUNKERS		-					2634		(1473)		
7. FINAL DEMAND (5 - 6)		N/A					(333)		7647		
8. THERMAL STATIONS		N/A					270		2987		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS									16		
12. OTHER GAS PRODUCTION											
13. REFINERIES							246				
14. CRUDE PRODUCTION											
15. MINES									286		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		N/A					183		10936		
19. TOTAL CONSUMPTION (6 + 18)		N/A					2817		9463		

ENERGY BALANCE

1931

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS							320		1721		
2. INDUSTRY							106		270		
3. MINING							-		2031		
4. TRANSPORT							1810		2699		
5. INLAND FINAL CONSUMPTION (1 - 4)		N/A					2236		6721		
6. IMPORT BALANCE INCL. BUNKERS		-					2601		(2068)		
7. FINAL DEMAND (5 - 6)		N/A					(365)		8789		
8. THERMAL STATIONS		N/A					245		2836		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS									14		
12. OTHER GAS PRODUCTION											
13. REFINERIES							294				
14. CRUDE PRODUCTION											
15. MINES									355		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		N/A					174		11994		
19. TOTAL CONSUMPTION (6 + 18)		N/A					2775		9926		

ENERGY BALANCE

1930

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		162					443		1778		
2. INDUSTRY		366					98		280		
3. MINING		1420					-		2050		
4. TRANSPORT		179					1743		3048		
5. INLAND FINAL CONSUMPTION (1 - 4)		2127					2284		7156		
6. IMPORT BALANCE INCL. BUNKERS		-					2782		(2873)		
7. FINAL DEMAND (5 - 6)		2127					(498)		10029		
8. THERMAL STATIONS		327					223		3065		
9. HYDRO STATIONS									12		
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS							441				
12. OTHER GAS PRODUCTION											
13. REFINERIES									367		
14. CRUDE PRODUCTION											
15. MINES											
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		2454					166		13473		
19. TOTAL CONSUMPTION (6 + 18)		2454					2948		10600		

ENERGY BALANCE

1929

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		137					508		1562		
2. INDUSTRY		345					88		260		
3. MINING		1363					-		2131		
4. TRANSPORT		163					1842		3291		
5. INLAND FINAL CONSUMPTION (1 - 4)		2008					2438		7244		
6. IMPORT BALANCE INCL. BUNKERS		-					2871		(3573)		
7. FINAL DEMAND (5 - 6)		2008					(433)		10817		
8. THERMAL STATIONS		292					204		3085		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS									11		
12. OTHER GAS PRODUCTION											
13. REFINERIES							386				
14. CRUDE PRODUCTION											
15. MINES									437		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		2300					157		14350		
19. TOTAL CONSUMPTION (6 + 18)		2300					3028		10777		

ENERGY BALANCE

1928

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		113					363		1587		
2. INDUSTRY		300					72		268		
3. MINING		1253					-		2113		
4. TRANSPORT		141					1310		3264		
5. INLAND FINAL CONSUMPTION (1 - 4)		1807					1745		7232		
6. IMPORT BALANCE INCL. BUNKERS		-					2106		(3297)		
7. FINAL DEMAND (5 - 6)		1807					(361)		10529		
8. THERMAL STATIONS		303					183		2864		
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS									10		
12. OTHER GAS PRODUCTION											
13. REFINERIES							327				
14. CRUDE PRODUCTION											
15. MINES									493		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		2110					149		13896		
19. TOTAL CONSUMPTION (6 + 18)		2110					2255		10599		

ENERGY BALANCE

1927

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS		114					286				
2. INDUSTRY		352					56				
3. MINING		1099					-		2128		
4. TRANSPORT		129					1017		3107		
5. INLAND FINAL CONSUMPTION (1 - 4)		1694					1359				
6. IMPORT BALANCE INCL. BUNKERS		-					1578		(3639)		
7. FINAL DEMAND (5 - 6)		1694					(219)				
8. THERMAL STATIONS		195					162				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							200				
14. CRUDE PRODUCTION											
15. MINES									564		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1889					143		13867		
19. TOTAL CONSUMPTION (6 + 18)		1889					1721		10228		

ENERGY BALANCE

1926

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		119					282				
2. INDUSTRY							35				
3. MINING							-		2164		
4. TRANSPORT		116					913		3126		
5. INLAND FINAL CONSUMPTION (1 - 4)		1517					1230				
6. IMPORT BALANCE INCL. BUNKERS		-					1405		(4295)		
7. FINAL DEMAND (5 - 6)		1517					(175)				
8. THERMAL STATIONS		244					141				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							148				
14. CRUDE PRODUCTION											
15. MINES									541		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1761					114		14275		
19. TOTAL CONSUMPTION (6 + 18)		1761					1519		9980		

ENERGY BALANCE

1925

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		112					282				
2. INDUSTRY							29				
3. MINING							-		1740		
4. TRANSPORT		36					574		3107		
5. INLAND FINAL CONSUMPTION (1 - 4)		1376					885				
6. IMPORT BALANCE INCL. BUNKERS		-					890		(3713)		
7. FINAL DEMAND (5 - 6)		1376					(5)				
8. THERMAL STATIONS		205					132				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							(41)				
14. CRUDE PRODUCTION											
15. MINES									582		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1581					86		13582		
19. TOTAL CONSUMPTION (6 + 18)		1581					976		9869		

ENERGY BALANCE

1924

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS		100					270				
2. INDUSTRY							25				
3. MINING							-		2206		
4. TRANSPORT		32					514		2790		
5. INLAND FINAL CONSUMPTION (1 - 4)		1268					809				
6. IMPORT BALANCE INCL. BUNKERS		-					1001		(3733)		
7. FINAL DEMAND (5 - 6)		1268					(192)				
8. THERMAL STATIONS		174					125				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							124				
14. CRUDE PRODUCTION											
15. MINES									537		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1442					57		13029		
19. TOTAL CONSUMPTION (6 + 18)		1442					1058		9296		

ENERGY BALANCE

1923

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		80					208				
2. INDUSTRY							21				
3. MINING							-		2150		
4. TRANSPORT		31					396		2645		
5. INLAND FINAL CONSUMPTION (1 - 4)		1050					625				
6. IMPORT BALANCE INCL. BUNKERS		-					701		(3708)		
7. FINAL DEMAND (5 - 6)		1050					(76)				
8. THERMAL STATIONS		142					119				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							3				
14. CRUDE PRODUCTION											
15. MINES									487		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1192					46		12404		
19. TOTAL CONSUMPTION (6 + 18)		1192					747		8696		

ENERGY BALANCE

1922

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS		70					237				
2. INDUSTRY							16				
3. MINING							-		1672		
4. TRANSPORT		26					292		2258		
5. INLAND FINAL CONSUMPTION (1 - 4)		1077					545				
6. IMPORT BALANCE INCL. BUNKERS		-					604		(2900)		
7. FINAL DEMAND (5 - 6)		1077					(59)				
8. THERMAL STATIONS		141					112				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							(19)				
14. CRUDE PRODUCTION											
15. MINES									487		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1218					34		10221		
19. TOTAL CONSUMPTION (6 + 18)		1218					638		7321		

ENERGY BALANCE

1921

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS		46					216				
2. INDUSTRY							14				
3. MINING							-		2099		
4. TRANSPORT		27					300		2432		
5. INLAND FINAL CONSUMPTION (1 - 4)		1135					530				
6. IMPORT BALANCE INCL. BUNKERS		-					721		(3422)		
7. FINAL DEMAND (5 - 6)		1135					(191)				
8. THERMAL STATIONS		141					105				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							109				
14. CRUDE PRODUCTION											
15. MINES									525		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1276					23		11922		
19. TOTAL CONSUMPTION (6 + 18)		1276					744		8500		

ENERGY BALANCE

1920

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		43					221				
2. INDUSTRY							10				
3. MINING							-		2339		
4. TRANSPORT		24					284		2746		
5. INLAND FINAL CONSUMPTION (1 - 4)		1142					515				
6. IMPORT BALANCE INCL. BUNKERS		-					595		(3151)		
7. FINAL DEMAND (5 - 6)		1142					(80)				
8. THERMAL STATIONS		135					99				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							(2)				
14. CRUDE PRODUCTION											
15. MINES									567		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1277					17		12040		
19. TOTAL CONSUMPTION (6 + 18)		1277					612		8889		

ENERGY BALANCE

1919

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS		39					190				
2. INDUSTRY							5				
3. MINING							-		2516		
4. TRANSPORT		22					198		2470		
5. INLAND FINAL CONSUMPTION (1 - 4)		1086					393				
6. IMPORT BALANCE INCL. BUNKERS		-					443		(2517)		
7. FINAL DEMAND (5 - 6)		1086					(50)				
8. THERMAL STATIONS		133					87				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							(26)				
14. CRUDE PRODUCTION											
15. MINES									589		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1219					11		10855		
19. TOTAL CONSUMPTION (6 + 18)		1219					454		8338		

ENERGY BALANCE

1918

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS		53					154				
2. INDUSTRY							4				
3. MINING							-		2471		
4. TRANSPORT		21					140		2272		
5. INLAND FINAL CONSUMPTION (1 - 4)		1058					298				
6. IMPORT BALANCE INCL. BUNKERS		-					458		(2491)		
7. FINAL DEMAND (5 - 6)		1058					(160)				
8. THERMAL STATIONS		123					76				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							93				
14. CRUDE PRODUCTION											
15. MINES									548		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		1181					9		10425		
19. TOTAL CONSUMPTION (6 + 18)		1181					467		7934		

ENERGY BALANCE

1917

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		43					259				
2. INDUSTRY							3				
3. MINING							-		2537		
4. TRANSPORT		21					176		2382		
5. INLAND FINAL CONSUMPTION (1 - 4)		851					438				
6. IMPORT BALANCE INCL. BUNKERS		-					671		(2872)		
7. FINAL DEMAND (5 - 6)		851					(233)				
8. THERMAL STATIONS		91					57				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							183				
14. CRUDE PRODUCTION											
15. MINES									566		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)		942					7		10949		
19. TOTAL CONSUMPTION (6 + 18)		942					678		8077		

ENERGY BALANCE

1916

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS							266				
2. INDUSTRY							2				
3. MINING							-		2507		
4. TRANSPORT							142		2305		
5. INLAND FINAL CONSUMPTION (1 - 4)							410				
6. IMPORT BALANCE INCL. BUNKERS							569		(2716)		
7. FINAL DEMAND (5 - 6)							(159)				
8. THERMAL STATIONS							41				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							121				
14. CRUDE PRODUCTION											
15. MINES									231		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)							3		10239		
19. TOTAL CONSUMPTION (6 + 18)							572		7523		

ENERGY BALANCE

1915

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS							265				
2. INDUSTRY							-				
3. MINING							-		2241		
4. TRANSPORT							128		1875		
5. INLAND FINAL CONSUMPTION (1 - 4)							393				
6. IMPORT BALANCE INCL. BUNKERS							425		(1785)		
7. FINAL DEMAND (5 - 6)							(32)				
8. THERMAL STATIONS							7				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							25				
14. CRUDE PRODUCTION											
15. MINES									181		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)							-		8462		
19. TOTAL CONSUMPTION (6 + 18)							425		6677		

ENERGY BALANCE

1914

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS							285				
2. INDUSTRY							-				
3. MINING							-		2108		
4. TRANSPORT							109		1929		
5. INLAND FINAL CONSUMPTION (1 - 4)							394				
6. IMPORT BALANCE INCL. BUNKERS							391		(1934)		
7. FINAL DEMAND (5 - 6)							3				
8. THERMAL STATIONS							5				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							(8)				
14. CRUDE PRODUCTION											
15. MINES									154		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)							-		8632		
19. TOTAL CONSUMPTION (6 + 18)							391		6698		

ENERGY BALANCE

1913

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS							279				
2. INDUSTRY							-				
3. MINING							-		2535		
4. TRANSPORT							112		1895		
5. INLAND FINAL CONSUMPTION (1 - 4)							391				
6. IMPORT BALANCE INCL. BUNKERS							414		(2254)		
7. FINAL DEMAND (5 - 6)							(23)				
8. THERMAL STATIONS							3				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							20				
14. CRUDE PRODUCTION											
15. MINES									104		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)							-		8905		
19. TOTAL CONSUMPTION (6 + 18)							414		6651		

ENERGY BALANCE

1912

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS							251				
2. INDUSTRY							-				
3. MINING							-		2472		
4. TRANSPORT							54		1672		
5. INLAND FINAL CONSUMPTION (1 - 4)							305				
6. IMPORT BALANCE INCL. BUNKERS							377		(1518)		
7. FINAL DEMAND (5 - 6)							(72)				
8. THERMAL STATIONS							2				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							70				
14. CRUDE PRODUCTION											
15. MINES									21		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)							-		8138		
19. TOTAL CONSUMPTION (6 + 18)							377		6620		

ENERGY BALANCE

1911

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS							227				
2. INDUSTRY							-				
3. MINING							-		2609		
4. TRANSPORT							34		1463		
5. INLAND FINAL CONSUMPTION (1 - 4)							261				
6. IMPORT BALANCE INCL. BUNKERS							331		(1456)		
7. FINAL DEMAND (5 - 6)							(70)				
8. THERMAL STATIONS							2				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							68				
14. CRUDE PRODUCTION											
15. MINES									72		
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)							-		7667		
19. TOTAL CONSUMPTION (6 + 18)							331		6211		

ENERGY BALANCE

1910

CONSUMPTION SECTOR.	ENERGY SOURCE	ELECTRICITY			GAS		LIQUID FUELS		SOLID FUELS		
		THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH			MILLION CUB.FT.		'000 BARRELS			'000 TONS	
1. HOUSEHOLDS							216				
2. INDUSTRY							-				
3. MINING							-				
4. TRANSPORT							23				
5. INLAND FINAL CONSUMPTION (1 - 4)							239				
6. IMPORT BALANCE INCL. BUNKERS							272		(1485)		
7. FINAL DEMAND (5 - 6)							(33)				
8. THERMAL STATIONS							2				
9. HYDRO STATIONS											
10. NUCLEAR STATIONS											
11. COAL GAS PRODUCERS											
12. OTHER GAS PRODUCTION											
13. REFINERIES							31				
14. CRUDE PRODUCTION											
15. MINES											
16. COKE PRODUCERS											
17. GAS COKE PRODUCTION											
18. PRODUCTION (7 - 17)							-				
19. TOTAL CONSUMPTION (6 + 18)							272				

3.5.2 Gas

(i) Coal gas

The relevant information pertaining to the six coal gas producers located at Johannesburg, Springs, Cape Town, Port Elizabeth, Grahamstown and Sasolburg, as discussed in section 2.2.6, has been obtained by means of postal surveys. The four major producers at Johannesburg, Sasolburg, Springs and Cape Town were also visited personally and it was generally found that their historical records on coal consumption, gas production, sales by consumption sector and own consumption, were well kept over long periods of time. In the case of the Johannesburg Municipal Gas Works, for instance, it was found that some of the required series were available as far back as the year 1892, (the gas-works commenced operations on 23rd June 1892).

On one or two occasions it was found necessary to estimate some of the required series for smaller undertakings, but, on the whole, the quality of coal gas data was fairly satisfactory.

The gas output of all producers was converted to equivalent quantities of standard town gas with a calorific value of 450 Btu per cubic foot.

(ii) Other gas

This category represents the aggregate of blast-furnace and coke-oven gas, produced by the iron and steel industry and coke-producers, respectively, and refinery gas.

A survey was again conducted, and questionnaires were sent to the various steel and coke producers, but the quality of the information received back (in a few cases there was no response

even after repeated representations) was such that it was decided to estimate the required statistics on the production and consumption of by-product coke-oven and blast-furnace gas. It was fairly easy to estimate the gas figures from the consumption of coking coal, for the production of coke, as there is a reasonably constant yield of gas from a ton of coal or coke if the processes involved are known. It is for instance known that, applying the conventional process, a ton of coking coal yields about 1400 lbs. of coke and about 11,000 cubic feet of by-product gas of a calorific value ranging between 550 to 575 Btu per cubic foot.⁷⁷

Refinery gas (C.V. equals 1900 Btu/cub.ft.) was converted to equivalent quantities of coke-oven gas with a calorific value of 550 Btu per cubic foot. Estimates on the production and consumption of refinery gas in South Africa were kindly made available by Mobil Oil S.A. (Pty) Limited.

As no information is available on the own consumption of this balance, consumption was assumed to equal production.

3.5.3 Liquid Fuels

Information on the production of refined petroleum products, and imports and exports of refined and crude oil, as outlined above by Tables 25 to 29, were obtained from the various sources of the Department of Customs and Excise.⁶⁵⁷ Consumption of refined oil products (as presented in Table 24, page 164), prior to 1939, was estimated on the basis of imports less re-exports,¹⁹⁷ since there was no significant local production during that period. Statistics quoted after 1939 were kindly supplied by Mobil Oil S.A. (Pty) Limited.

The breakdown of inland final consumption of refined oil over the four sectors of consumption raised a problem, as the required data were unavailable and had to be estimated. In estimating the sectoral breakdown of refined products, use has been made of unpublished statistics of the Department of Statistics and end-use estimates of petroleum demand, made by Mobil Oil S.A. (Pty) Limited.¹⁹⁷ In doing so, consumption of each product had to be broken down individually over the four sectors, and the final results are tabulated in Appendix 1, in a series of tables for the years 1910 to 1968. (Appendix 1 is provided at the back of this book). This exercise was, however, greatly simplified by the fact that some refined oil products are consumed for certain specific end-uses, e.g., petrol and aviation fuel are exclusively consumed for transport purposes. The demands of the agricultural sector are included in the domestic sector, in accordance with the comments made in Section 3.4.

The figures appearing in the crude liquid fuels column for production relate, of course, to the synthetic crude produced from coal by Sasol, as there is no conventional crude oil production in South Africa at present. There are no detailed published statistics available on the production of synthetic crude by Sasol. In the State of South Africa Year Book⁶⁴⁷ for 1965 it is indicated, however, that Sasol produces about 62 million gallons of petrol and other liquid products a year. The required series have, therefore, been estimated by taking the 1965 production at 62 million gallons and increasing it thereafter in proportion to the quantities of coal consumed by the oil from coal plant.

3.5.4 Solid fuels

(i) Coal

In section 2.2.5, it was indicated that reliable data on total inland consumption of coal are somewhat scant, and that

there is still considerable disagreement on the precise sectoral distribution of total demand. In Table 17, the total demand for coal was, therefore, estimated on the basis of production plus imports, minus exports and bunkers (page 108). The series on sales were constructed from data provided by the Jubilee Issue of Statistics,^{42/} the various Statistical Yearbooks^{71/} and Quarterly Bulletins of Statistics.^{41/} Information on the external trade was obtained from the Annual Imports and Exports Yearbooks^{65/} of the Department of Customs and Excise.

The total inland consumption of coal was then broken down by sector, as shown in Table 18. In the build-up of this table, every bit of information available on the subject was collected, examined, adjusted and the aggregate sectors checked against the total, as established in Table 17.

The sources used to construct Table 18 included, inter alia, information kindly made available by Sasol, the Coal Bureau and the Fuel Research Institute, Escom, the Trans-Natal Coal Corporation Limited and The South African Railways and Harbours Administration. Published sources include Kotze (1967),^{19/} Coulter (1930),^{23/} Hall (1948),^{27/} Visser and Hastie (1965),^{45/} Human (1967),^{14/} Shilling (1969)^{24/} and Grant (1959).^{25/} In addition, two surveys were undertaken, the first relating to coal consumed for power generation by self-producers, and the second relating to coal used for town gas production. In both cases, a 100 per cent response was obtained. In the case of the first survey, questionnaires were sent, amongst others, to those 27 Municipalities which have used coal as a primary source for the generation of electricity in their own Municipal electricity undertakings over the last twenty years. Information was also obtained from Sasol on the coal

consumption of the Sasol power station at Sasolburg and from a few other self-producers. By means of the second survey, the historical figures on coal consumed by the six town gas producers were obtained, including Gascor, as previously outlined.

The partial energy balance for coal was, therefore, constructed from the series discussed above, and finally completed by adding production statistics obtained from official sources. ^{42/71/41/}

(ii) Coke

As already indicated in section 3.5.2, a further survey was conducted on the historical production of coke and coke-oven gas. Although detailed information of a high quality was obtained from Iscor, the major coke producer, and from Amcor, repeated enquiries addressed to other producers, of which aggregate production represents a not insignificant part of the total, failed to bring forth the necessary co-operation. It was therefore decided to estimate the production of coke in South Africa on the basis of coking coal consumed (column 5, Table 18). On the average, a ton of coking coal yields about 67 per cent, by weight, of coke. It was assumed that consumption was the same as production.

(iii) Gas-coke

The relevant information, as indicated in the partial balance sheet corresponding to this source of energy, was obtained by means of a survey, already mentioned in section 3.5.2.

In this way, completely integrated energy balance sheets illustrating the historical development of the South African energy economy, year by year, were obtained. These energy balances are only complete from 1933 onwards as no official data are available on electricity for the years 1931 and 1932.

3.6 Historical trends in useful energy consumption

In order to determine total energy consumption and the contribution of each source of energy to the total, it is necessary to convert final consumption to a common denominator. This is done by applying the method of conversion into useful energy which was discussed in section 1.9.1.2 (iii), and which involved the adoption of specific indices for the useful energy content of the various energy-producing agents.

In doing so, the demand for each energy-producing agent, contributing to final demand, is converted to useful energy, expressed in joules, by taking the calorific value and efficiency of conversion (as expressed in percentages) for each energy-producing agent into account.

A fixed percentage yield of useful energy, considered representative over the entire period under observation, is assumed for each energy-producing agent in each sector. The development of the demand for energy is, therefore, not affected by cross-substitution of sources of energy with different yields of useful energy. In this way, it is possible to distinguish, in the analysis, between the influence of substitution on the demand for energy and the influence of a steadily increasing trend in the efficiency of consumption. The advantage of this procedure is that the absolute magnitudes of the different yields of useful energy need not be known in the analysis.²⁰⁷

In establishing useful energy consumption, the following average

calorific values were used for the various sources of energy; coal, 11500 Btu per pound weight; coke-oven coke, 12000 Btu per pound; gas-coke, 11000 Btu per pound; coal gas, 450 Btu per cubic feet; other gas, 550 Btu per cubic feet; and refined petroleum, 6.2 million Btu per barrel.

No information is available on the efficiencies at which the various energy-producing agents are, and have been, finally consumed in South Africa. The available sectoral distributions of the final consumptions of all sources of energy, except for electricity, do, however, allow a breakdown by form of useful energy consumed. In the case of coal, for instance, the demand in all sectors is for the generation of heat, except in the transport sector where demand represents coal used by the Railways for the generation of mechanical power. The entire demand for all varieties of gas and coke is, as it is known, applied for the generation of heat. Lastly, available statistics on the final demand for refined oil make it possible to classify its end-use by form of useful energy consumed.

The same is of course not true of the demand for electricity. Exhaustive enquiries established that data on the breakdown of electricity by form of useful energy consumed are unobtainable.

It was, therefore, decided to adopt statistics in use in other countries on the efficiency of final conversion; as set out in Tables 1 to 4. It is felt that differences between South Africa and these countries, if they exist, will be small, as the efficiency of converting petrol into mechanical power by the internal combustion engine, for instance, will be the same in Europe and South Africa. Similarly, the efficiencies applying to comparable boilers, here and overseas, should be about the same.

Table 35 provides percentages of conversion efficiencies for each source of energy, by sector, which are considered representative over the period under review, and which have been selected as the basis for this study.

TABLE 35: EFFICIENCY OF CONVERSION INTO
USEFUL ENERGY, IN PER CENT

SECTOR	ELECTRICITY	COAL GAS	OTHER GAS	REFINED OIL	COAL	COKE	GAS COKE
HOUSEHOLDS	80 24 @	65		1)	20		30
INDUSTRY	80 130 PE	80	80	40	45	50	50
MINING	80			20	45		
TRANSPORT	80			20	5		

- 1) Heat - 65 per cent
Mechanical energy - 20 per cent

By applying these efficiencies to the physical energy content of each energy-producing agent in the final consumption sector of the energy balance, equivalent quantities of useful energy consumed are obtained. In this way, the total energy consumed is derived, in each sector of final consumption, and for each energy-producing agent, over all sectors, as set out in Tables 36 to 40.

Tables 41 to 45 provide the market shares of the various energy-producing agents in each sectoral total and for the grand total.

By using these schedules in combination, it is now possible to make a reasonable study of the historical forces at work in the energy economy.

TABLE 36 : USEFUL ENERGY CONSUMPTION - HOUSEHOLDS SECTOR

(10⁶ MEGAJOULES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	732	7,520	1,450	87			14	9,803
1934	887	8,080	1,900	99			14	10,980
1935	1,066	8,680	1,680	119			14	11,559
1936	1,130	9,200	1,860	150			28	12,368
1937	1,498	9,800	2,160	179			35	13,672
1938	1,757	10,360	2,130	195			35	14,477
1939	1,976	9,880	2,780	219			42	14,897
1940	2,182	10,400	2,470	242			42	15,336
1941	2,339	10,920	2,810	257			49	16,375
1942	2,485	11,480	4,210	263			49	18,487
1943	2,555	12,000	3,120	317			56	18,048
1944	2,696	12,360	3,440	337			56	18,889
1945	2,854	11,840	3,670	349			56	18,769
1946	3,136	12,200	4,300	365			63	20,064
1947	3,473	12,600	4,810	405			63	21,351
1948	3,868	13,920	5,570	429			70	23,857
1949	4,211	14,320	6,360	440			84	25,415
1950	4,778	14,760	6,770	433			84	26,825
1951	5,394	15,200	7,660	447			91	28,792
1952	5,846	16,000	8,100	475			125	30,546
1953	6,523	15,320	8,920	478			110	31,351
1954	7,125	14,240	9,770	490			118	31,743
1955	7,701	15,320	10,220	509			104	33,854
1956	8,562	15,120	10,770	513			97	35,062
1957	9,749	14,840	11,130	514			104	36,337
1958	9,677	14,800	11,550	527			97	36,651
1959	10,241	15,840	12,070	529			104	38,784
1960	10,924	15,560	12,120	543			91	39,238
1961	11,667	15,120	13,160	524			77	40,548
1962	11,379	14,520	13,680	521			84	40,184
1963	11,958	15,760	14,520	564			125	42,927
1964	12,957	16,520	15,470	571			104	45,622
1965	13,994	19,160	16,150	578			97	49,979
1966	14,651	17,800	16,820	573			104	49,948
1967	16,321	17,560	17,760	511			132	52,284
1968	17,464	16,960	18,500	474			118	53,516

TABLE 37 : USEFUL ENERGY CONSUMPTION - INDUSTRIAL SECTOR
(10⁶ MEGAJOULES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	1,313	2,730	306	71	1,020	2,492	162	8,094
1934	1,662	6,450	319	71	1,280	4,371	186	14,339
1935	1,840	6,330	321	77	2,041	4,985	197	15,791
1936	2,477	8,460	306	84	2,296	5,617	220	19,460
1937	2,782	8,280	301	91	2,756	6,733	255	21,198
1938	3,053	11,190	256	93	3,429	8,370	267	26,638
1939	3,303	11,520	261	96	3,715	9,077	279	28,251
1940	3,839	10,950	217	104	3,593	8,779	290	27,772
1941	4,248	12,250	220	107	4,144	10,118	302	31,389
1942	4,605	16,510	227	116	5,746	14,024	325	41,553
1943	4,971	20,470	227	141	5,793	14,155	370	46,127
1944	5,129	22,580	248	155	5,930	14,489	370	48,901
1945	5,435	21,680	259	163	6,149	15,010	395	49,091
1946	5,584	24,670	301	172	6,251	15,271	406	52,655
1947	5,743	19,150	489	199	6,670	16,294	429	48,974
1948	6,356	26,040	711	215	7,175	17,521	453	58,471
1949	7,116	35,060	858	225	8,624	21,055	499	73,437
1950	8,116	34,760	1,043	226	9,058	22,115	499	75,817
1951	8,626	37,340	1,203	243	10,574	25,817	545	84,348
1952	9,570	50,920	1,226	256	10,875	26,561	673	100,081
1953	9,919	46,450	1,370	250	11,334	27,677	603	97,603
1954	11,203	38,200	1,504	273	12,809	31,285	615	95,889
1955	12,967	42,690	1,595	295	12,809	31,285	615	102,256
1956	13,974	52,730	1,702	310	13,830	33,776	603	116,925
1957	15,659	59,370	2,013	309	14,340	35,024	603	127,318
1958	16,194	58,430	2,312	348	14,953	36,512	615	129,364
1959	17,142	49,380	2,458	366	17,657	43,115	592	130,710
1960	18,265	62,470	2,581	399	18,423	44,993	557	147,688
1961	20,287	58,890	3,086	395	19,290	47,114	499	149,561
1962	22,378	66,090	3,789	390	20,311	49,606	534	163,098
1963	25,036	60,340	5,031	410	20,668	50,480	720	162,685
1964	27,590	70,450	6,148	440	22,607	55,205	627	183,067
1965	30,989	73,980	7,873	473	26,894	65,677	627	206,513
1966	33,402	61,390	10,614	582	27,558	67,295	638	201,479
1967	36,662	56,320	12,776	1,313	29,223	69,397	708	206,399
1968	41,063	65,660	14,492	2,255	32,038	73,079	580	229,167

TABLE 38 : USEFUL ENERGY CONSUMPTION - MINING SECTOR

(10⁶ MEGAJOULES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	4,582	20,200	-					24,782
1934	5,126	21,800	-					26,926
1935	5,812	23,000	3					28,815
1936	6,589	24,600	8					31,197
1937	7,494	24,900	11					32,405
1938	8,274	26,600	13					34,887
1939	9,219	26,000	14					35,233
1940	10,331	26,300	14					36,645
1941	10,800	26,800	14					37,614
1942	11,030	26,700	14					37,744
1943	10,506	25,900	16					36,422
1944	10,696	26,700	17					37,413
1945	10,878	27,200	18					38,096
1946	10,935	31,600	33					42,568
1947	10,892	26,900	72					37,864
1948	11,526	31,000	124					42,650
1949	12,393	27,600	176					40,169
1950	13,467	24,300	224					37,991
1951	13,913	20,900	237					35,050
1952	14,662	17,600	251					32,513
1953	15,140	17,000	267					32,407
1954	16,572	16,800	284					33,656
1955	18,423	18,000	302					36,725
1956	20,644	17,200	322					38,166
1957	21,580	16,700	341					38,621
1958	21,629	24,300	363					46,292
1959	22,363	17,000	387					39,750
1960	23,723	16,600	412					40,735
1961	25,332	16,800	439					42,571
1962	26,268	14,600	469					41,337
1963	27,429	21,300	501					49,230
1964	28,103	19,400	535					48,038
1965	30,989	15,700	571					47,260
1966	31,032	16,400	611					48,043
1967	32,950	15,800	652					49,402
1968	34,546	16,400	703					51,649

TABLE 39 : USEFUL ENERGY CONSUMPTION - TRANSPORT SECTOR

(10⁶ MEGAJOULES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	464	3,430	2,670					6,564
1934	544	3,630	3,100					7,274
1935	631	4,040	3,660					8,331
1936	665	4,340	4,500					9,505
1937	786	4,930	5,570					11,286
1938	1,022	4,380	6,280					11,682
1939	1,207	4,710	6,720					12,637
1940	1,279	4,980	6,710					12,969
1941	1,348	5,160	6,940					13,448
1942	1,371	5,390	6,150					12,911
1943	1,374	5,510	5,670					12,554
1944	1,408	5,720	5,700					12,828
1945	1,403	6,080	5,530					13,013
1946	1,477	6,250	7,560					15,287
1947	1,475	6,600	9,210					17,285
1948	1,547	6,830	10,770					19,147
1949	1,708	6,750	12,090					20,548
1950	1,719	6,770	12,290					20,779
1951	2,232	7,130	13,280					22,642
1952	2,275	7,670	13,820					23,765
1953	2,419	7,710	14,430					24,559
1954	1,999	7,970	15,050					25,019
1955	2,120	8,260	16,240					26,620
1956	2,272	8,550	17,270					28,092
1957	2,376	9,320	18,680					30,376
1958	2,385	9,870	20,310					32,565
1959	2,474	8,920	21,160					32,554
1960	2,771	8,780	22,350					33,901
1961	3,102	8,370	23,340					34,812
1962	3,525	8,430	24,410					36,365
1963	3,851	8,370	26,120					38,341
1964	4,090	8,300	28,870					41,260
1965	4,784	8,970	31,980					45,734
1966	5,181	8,330	35,230					48,741
1967	5,463	7,750	37,960					51,173
1968	5,962	7,830	41,330					55,122

TABLE 40 : USEFUL ENERGY CONSUMPTION - GRAND TOTAL

(10⁶ MEGAJOULES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	7,091	33,880	4,426	158	1,020	2,492	176	49,243
1934	8,219	39,960	5,319	170	1,280	4,371	200	59,519
1935	9,349	42,050	5,664	196	2,041	4,985	211	64,496
1936	10,861	46,600	6,674	234	2,296	5,617	248	72,530
1937	12,560	47,910	8,042	270	2,756	6,733	290	78,561
1938	14,106	52,530	8,679	288	3,429	8,370	302	87,704
1939	15,705	52,110	9,775	315	3,715	9,077	321	91,018
1940	17,631	52,630	9,411	346	3,593	8,779	332	92,722
1941	18,735	55,130	9,984	364	4,144	10,118	351	98,826
1942	19,491	60,080	10,601	379	5,746	14,024	374	110,695
1943	19,406	63,880	9,033	458	5,793	14,155	426	113,151
1944	19,929	67,360	9,405	492	5,930	14,489	426	118,031
1945	20,570	66,800	9,477	512	6,149	15,010	451	118,969
1946	21,132	74,720	12,194	537	6,251	15,271	469	130,574
1947	21,583	65,250	14,581	604	6,670	16,294	492	125,474
1948	23,297	77,790	17,175	644	7,175	17,521	523	144,125
1949	25,428	83,730	19,484	665	8,624	21,055	583	159,569
1950	28,080	80,590	20,327	659	9,058	22,115	583	161,412
1951	30,165	80,570	22,380	690	10,574	25,817	636	170,832
1952	32,353	92,190	23,397	731	10,875	26,561	798	186,905
1953	34,001	86,480	24,987	728	11,334	27,677	713	185,920
1954	36,899	77,210	26,608	763	12,809	31,285	733	186,307
1955	41,211	84,270	28,357	804	12,809	31,285	719	199,455
1956	45,452	93,600	30,064	823	13,830	33,776	700	218,245
1957	49,364	100,230	32,164	823	14,340	35,024	707	232,652
1958	49,885	107,400	34,535	875	14,953	36,512	712	244,872
1959	52,220	91,740	36,075	895	17,657	43,115	696	241,798
1960	55,683	103,410	37,463	942	18,423	44,993	648	261,562
1961	60,388	99,180	40,025	919	19,290	47,114	576	267,492
1962	63,550	103,640	42,348	911	20,311	49,606	618	280,984
1963	68,274	105,770	46,172	974	20,668	50,480	845	293,183
1964	72,740	114,670	51,023	1,011	22,607	55,205	731	317,987
1965	80,756	117,810	56,574	1,051	26,894	65,677	724	349,486
1966	84,266	103,920	63,275	1,155	27,558	67,295	742	348,211
1967	91,396	97,430	69,148	1,824	29,223	69,397	840	359,258
1968	99,035	106,850	75,025	2,729	32,038	73,079	698	389,454

TABLE 41 : MARKET SHARES OF FORMS OF ENERGY IN THE HOUSEHOLD SECTOR

(PERCENTAGES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	7.5	76.7	14.8	.9			.1	100
1934	8.1	73.6	17.3	.9			.1	100
1935	9.2	75.1	14.6	1.0			.1	100
1936	9.2	74.4	15.0	1.2			.2	100
1937	11.0	71.7	15.8	1.2			.3	100
1938	12.2	71.6	14.7	1.3			.2	100
1939	13.2	66.3	18.7	1.5			.3	100
1940	14.2	67.8	16.1	1.6			.3	100
1941	14.3	66.7	17.1	1.6			.3	100
1942	13.4	62.1	22.8	1.4			.3	100
1943	14.2	66.5	17.2	1.8			.3	100
1944	14.3	65.4	18.2	1.8			.3	100
1945	15.2	63.1	19.5	1.9			.3	100
1946	15.6	60.8	21.5	1.8			.3	100
1947	16.3	59.0	22.5	1.9			.3	100
1948	16.2	58.4	23.3	1.8			.3	100
1949	16.6	56.4	25.0	1.7			.3	100
1950	17.8	55.1	25.2	1.6			.3	100
1951	18.7	52.8	26.6	1.6			.3	100
1952	19.1	52.4	26.5	1.6			.4	100
1953	20.8	48.8	28.5	1.5			.4	100
1954	22.4	44.9	30.8	1.5			.4	100
1955	22.7	45.3	30.2	1.5			.3	100
1956	24.4	43.1	30.7	1.5			.3	100
1957	26.8	40.9	30.6	1.4			.3	100
1958	26.4	40.4	31.5	1.4			.3	100
1959	26.4	40.8	31.1	1.4			.3	100
1960	27.8	39.7	30.9	1.4			.2	100
1961	28.8	37.3	32.4	1.3			.2	100
1962	28.3	36.2	34.0	1.3			.2	100
1963	27.9	36.7	33.8	1.3			.3	100
1964	28.4	36.2	33.9	1.3			.2	100
1965	28.0	38.3	32.3	1.2			.2	100
1966	29.3	35.6	33.7	1.2			.2	100
1967	31.2	33.5	34.0	1.0			.3	100
1968	32.6	31.7	34.6	.9			.2	100

TABLE 42: MARKET SHARES OF FORMS OF ENERGY IN THE INDUSTRIAL SECTOR

(PERCENTAGES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	16.2	33.7	3.8	.9	12.6	30.8	2.0	100
1934	11.6	45.0	2.2	.5	8.9	30.5	1.3	100
1935	11.7	40.1	2.0	.5	12.9	31.6	1.2	100
1936	12.7	43.4	1.6	.4	11.8	28.9	1.2	100
1937	13.1	39.1	1.4	.4	13.0	31.8	1.2	100
1938	11.4	42.0	1.0	.3	12.9	31.4	1.0	100
1939	11.7	40.8	.9	.3	13.1	32.2	1.0	100
1940	13.8	39.4	.9	.4	12.9	31.6	1.0	100
1941	13.5	39.0	.8	.3	13.2	32.2	1.0	100
1942	11.1	39.7	.6	.3	13.8	33.7	.8	100
1943	10.8	44.4	.5	.3	12.6	30.6	.8	100
1944	10.5	46.2	.5	.3	12.1	29.6	.8	100
1945	11.1	44.2	.5	.3	12.4	30.7	.8	100
1946	10.6	46.9	.6	.3	11.8	29.0	.8	100
1947	11.7	39.1	1.0	.4	13.6	33.3	.9	100
1948	10.9	44.5	1.2	.4	12.2	30.0	.8	100
1949	9.7	47.7	1.2	.3	11.7	28.7	.7	100
1950	10.7	45.8	1.4	.3	11.9	29.2	.7	100
1951	10.2	44.3	1.4	.3	12.6	30.6	.6	100
1952	9.6	50.9	1.2	.3	10.8	26.5	.7	100
1953	10.2	47.6	1.4	.3	11.6	28.3	.6	100
1954	11.7	39.8	1.6	.3	13.4	32.6	.6	100
1955	12.7	41.7	1.6	.3	12.5	30.6	.6	100
1956	12.0	45.1	1.5	.3	11.8	28.8	.5	100
1957	12.3	46.6	1.6	.2	11.3	27.5	.5	100
1958	12.5	45.2	1.8	.3	11.6	28.1	.5	100
1959	13.0	37.8	1.9	.3	13.5	33.0	.5	100
1960	12.4	42.2	1.7	.3	12.5	30.5	.4	100
1961	13.5	39.4	2.1	.3	12.9	31.5	.3	100
1962	13.7	40.5	2.3	.2	12.5	30.5	.3	100
1963	15.4	37.1	3.1	.3	12.7	31.0	.4	100
1964	15.1	38.5	3.4	.2	12.3	30.2	.3	100
1965	15.0	35.8	3.8	.2	13.0	31.9	.3	100
1966	16.6	30.5	5.3	.3	13.6	33.4	.3	100
1967	17.8	27.3	6.2	.6	14.2	33.6	.3	100
1968	17.9	28.6	6.3	1.0	14.0	31.9	.3	100

TABLE 43 : MARKET SHARES OF FORMS OF ENERGY IN THE MINING SECTOR

(PERCENTAGES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	18.5	81.5						100
1934	19.0	81.0						100
1935	20.2	79.8						100
1936	21.1	78.9						100
1937	23.2	76.8						100
1938	23.8	76.2						100
1939	26.2	73.8						100
1940	28.2	71.8						100
1941	28.7	71.3						100
1942	29.3	70.7						100
1943	28.6	71.4						100
1944	28.6	71.4						100
1945	25.7	74.2	.1					100
1946	28.8	71.0	.2					100
1947	28.8	71.0	.2					100
1948	27.0	72.7	.3					100
1949	30.9	68.7	.4					100
1950	35.4	64.0	.6					100
1951	39.7	59.6	.7					100
1952	45.1	54.1	.8					100
1953	46.7	52.5	.8					100
1954	49.2	49.9	.9					100
1955	50.2	49.0	.8					100
1956	54.1	45.1	.8					100
1957	55.9	43.2	.9					100
1958	46.7	52.5	.8					100
1959	56.3	42.8	.9					100
1960	58.2	40.8	1.0					100
1961	59.5	39.5	1.0					100
1962	63.5	35.3	1.2					100
1963	55.7	43.3	1.0					100
1964	58.5	40.4	1.1					100
1965	65.6	33.2	1.2					100
1966	64.6	34.1	1.3					100
1967	66.7	32.0	1.3					100
1968	66.9	31.8	1.3					100

TABLE 44: MARKET SHARES OF FORMS OF ENERGY IN THE TRANSPORT SECTOR

(PERCENTAGES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	7.1	52.2	40.7					100
1934	7.5	49.9	42.6					100
1935	7.6	48.5	43.9					100
1936	7.0	45.7	47.3					100
1937	7.0	43.7	49.3					100
1938	8.7	37.5	53.8					100
1939	9.6	37.3	53.1					100
1940	9.9	38.4	51.7					100
1941	10.0	38.4	51.6					100
1942	10.6	41.7	47.7					100
1943	10.9	43.9	45.2					100
1944	11.0	44.6	44.4					100
1945	10.8	46.7	42.5					100
1946	9.7	40.9	49.4					100
1947	8.5	38.2	53.3					100
1948	8.1	35.7	56.2					100
1949	8.3	32.9	58.8					100
1950	8.3	32.6	59.1					100
1951	9.9	31.5	58.6					100
1952	9.6	32.3	58.1					100
1953	9.8	31.4	58.8					100
1954	8.0	31.9	60.1					100
1955	8.0	31.0	61.0					100
1956	8.1	30.4	61.5					100
1957	7.8	30.7	61.5					100
1958	7.3	30.3	62.4					100
1959	7.6	27.4	65.0					100
1960	8.2	25.9	65.9					100
1961	8.9	24.0	67.1					100
1962	9.7	23.2	67.1					100
1963	10.0	21.8	68.2					100
1964	9.9	20.1	70.0					100
1965	10.5	19.6	69.9					100
1966	10.6	17.1	72.3					100
1967	10.7	15.1	74.2					100
1968	10.8	14.2	75.0					100

TABLE 45 : MARKET SHARES OF FORMS OF ENERGY - TOTAL ALL SECTORS

(PERCENTAGES)

YEAR	ELECTRICITY	COAL	OIL	COAL GAS	OTHER GAS	COKE	GAS COKE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1933	14.4	68.8	9.0	.3	2.1	5.0	.4	100
1934	13.8	67.1	9.0	.3	2.2	7.3	.3	100
1935	14.5	65.2	8.8	.3	3.2	7.7	.3	100
1936	15.0	64.3	9.2	.3	3.2	7.7	.3	100
1937	16.0	61.1	10.2	.3	3.5	8.6	.3	100
1938	16.1	60.0	9.9	.3	3.9	9.5	.3	100
1939	17.3	57.2	10.7	.3	4.1	10.0	.4	100
1940	19.0	56.8	10.1	.4	3.9	9.5	.3	100
1941	19.0	55.8	10.1	.4	4.2	10.2	.3	100
1942	17.6	54.3	9.6	.3	5.2	12.7	.3	100
1943	17.2	56.5	8.0	.4	5.1	12.5	.3	100
1944	16.9	57.1	8.0	.4	5.0	12.3	.3	100
1945	17.3	56.1	8.0	.4	5.2	12.6	.4	100
1946	16.2	57.2	9.3	.4	4.8	11.7	.4	100
1947	17.2	52.0	11.6	.5	5.3	13.0	.4	100
1948	16.1	54.0	11.9	.4	5.0	12.2	.4	100
1949	15.9	52.5	12.2	.4	5.4	13.2	.4	100
1950	17.4	49.9	12.6	.4	5.6	13.7	.4	100
1951	17.7	47.2	13.1	.4	6.2	15.0	.4	100
1952	17.4	49.3	12.5	.4	5.8	14.2	.4	100
1953	18.3	46.5	13.4	.4	6.1	14.9	.4	100
1954	19.8	41.4	14.3	.4	6.9	16.8	.4	100
1955	20.7	42.2	14.2	.4	6.4	15.7	.4	100
1956	20.8	42.9	13.8	.4	6.3	15.5	.3	100
1957	21.2	43.0	13.8	.4	6.2	15.1	.3	100
1958	20.4	43.9	14.0	.4	6.1	14.9	.3	100
1959	21.6	37.7	14.9	.4	7.3	17.8	.3	100
1960	21.3	39.5	14.3	.4	7.0	17.2	.3	100
1961	22.6	37.1	15.0	.3	7.2	17.6	.2	100
1962	22.6	36.9	15.1	.3	7.2	17.7	.2	100
1963	23.3	36.1	15.8	.3	7.0	17.2	.3	100
1964	22.9	36.1	16.0	.3	7.1	17.4	.2	100
1965	23.1	33.7	16.2	.3	7.7	18.8	.2	100
1966	24.2	29.8	18.2	.3	7.9	19.4	.2	100
1967	25.5	27.2	19.2	.5	8.1	19.3	.2	100
1968	25.4	27.4	19.3	.7	8.2	18.8	.2	100

3.6.1 Households sector

This is one of the smaller sectors of total final demand, representing 13.7 per cent of the total in 1968. The average annual rate of growth of the households sector, 1935 to 1968, is 5.0 per cent, which is slightly lower than the comparable rate of growth over all sectors, namely 6.1 per cent.

Oil holds the major market share in the sectoral total for 1968 (Table 41), closely followed by electricity and coal. The rapid rate of growth in the market share of oil in this sector reflects the degree to which mechanisation has taken place in the farming sector. (Agriculture is included in this sector.)

The sharp drop in the market share of coal and the corresponding increase in the market share of electricity is indicative of the trend towards the consumption of nobler forms of energy. One reason for this is that, with rising standards of living, consumer durables, such as domestic electrical appliances, come increasingly within the reach of more consumers.

3.6.2 Industrial sector

The industrial sector is by far the biggest sector, (58.8 per cent of the total in 1968), and has historically also grown the fastest. The average annual rate of growth in energy demand for this sector, over the last 35 years, is no less than 10 per cent, or about 40 per cent faster than the comparable growth-rate over all sectors. Over the last 10 years, however, growth has been slower, at an average 5.9 per cent annually.

From Table 42, it is evident that the contributions of the various energy sources to the total has more or less remained the same in this

sector over the last 35 years, except for a trend over the last 4 to 5 years which seems to suggest that oil and electricity may be displacing coal.

3.6.3 Mining sector

The mining sector is not only the smallest sector, (13.3 per cent of the total in 1968) but also shows the slowest growth. The average annual increase of 2.1 per cent in useful energy consumed in this sector since 1933 is considerably below the average for all sectors.

Table 43 indicates the rapid displacement of coal by electricity as a source of energy in this sector, and the share of electricity (66.9 per cent in 1968) illustrates afresh the importance of this sector to the electricity industry.

3.6.4 Transport sector

Although the transport sector is the second biggest sector in final demand, (14.2 per cent of the total in 1968) it is still considerably smaller than the industrial sector and only marginally bigger than the households and mining sectors.

Table 44 illustrates the rapid increase in the market share of oil and its predominance in the sector today (75 per cent in 1968). It is not, however, the result of substitution tendencies, but reflects the rapid increase in energy consumption for road transport purposes.

Electricity and coal consumed in this sector represent, of course, the demands of the rail transport sector and the figures show the substitution of coal by electricity as a source of energy. The fact that the increase in market share of electricity over the period has been much smaller than the decrease in market share for coal is indicative of the superior efficiency of electricity. The steam locomotive is notorious for the low efficiency with which it utilises coal (see Table 2).

3.6.5 Total all sectors

The growth in total useful energy consumption in South Africa since 1933, an average of 6.1 per cent annually, is a bit higher than the comparable growth rates in mature Western economies. Once an economy has reached a certain degree of maturity, the demand for energy grows at about 4.5 per cent annually. The rapid growth experienced over the last 35 years, as has been seen, is almost entirely the result of the rapid industrialisation of the South African economy.

Table 45 illustrates the trend towards more refined, flexible, secondary forms of energy, at the expense of coal. It has already been noted that the demand for high quality forms of energy follows in the wake of increased technological sophistication. Table 45 indicates that coal is still the most important energy-producing agent in the sector of final consumption, but that it is being increasingly challenged by electricity and oil. The rapid increase in the market shares of coke and other gas reflects the growth and importance of the Republic's metallurgical industries.

PART II

FORECASTING OF THE ENERGY ECONOMY

CHAPTER 4

THE FORECASTING PROBLEM

4.1 Introduction

The forecaster, whether in the firm or in the industry, can control only some of the factors on which his success depends. Setting aside, therefore, the difficulties of defining success and the uncertainties of the world, the forecaster must try to estimate the responses to be expected from his environment, for example, how customers are likely to respond to a change in his price, and also his own freedom of action over the factors he can control, for example, the conditions under which one raw material can be substituted for another in his production process. His problem, then, is to manipulate the factors he controls so as to achieve as much success as possible. In trying to do this, he inevitably faces a problem of interdependence, which, in the context of this study, cannot be better described than by quoting the United Kingdom National Coal Board.⁷⁵

'At the outset, the Board was faced with a series of circular arguments. Thus the future demand for coal depends on price; price turns on costs of production and delivery; costs on how much coal has to be produced, of what kinds, and where, which in turn depends on the demand. The circle is complete. Similarly, costs of production depend on wages, but wages may depend among other things on manpower needs; they in turn depend on production plans which themselves depend on costs of production in the future. Costs, again, depend on production techniques, production techniques on

capital investment and capital investment on costs.'

This quotation brings out the complex nature of the problems facing a producer considered in isolation. There are further complicating factors, however, which concern not only the decision-makers in each separate fuel industry but also the coordinating policy-makers in the relevant government departments; for each fuel industry produces a range of products which have different end uses, and some of these products are in direct competition with each other for a given end use, for example, fuel oil and coal for industrial bulk heating, or gas and electricity for domestic cooking. In attempting to forecast future fuel demands, care must therefore be taken to investigate to what extent and how fast one fuel can be substituted for another in a given end use.

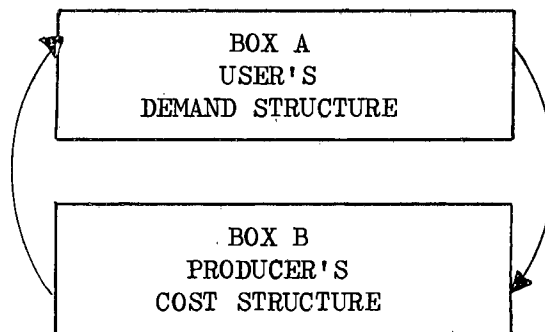
A study of the fuel sector cannot then treat each fuel separately but must treat the fuel commodities as a group. That this is a pressing problem for those who guide and control the fuel industries can be seen from statements made by the United Kingdom National Board for Prices and Incomes when considering proposed increases in the price of coal in 1966.⁷⁶⁷

'This failure to meet the pass rate of return (on new investment in collieries) has been due to two principal causes. First, investment has proved excessive in relation to market demand..... These (demand forecasts) have proved to be over estimates. By basing its estimates on present prices and costs the Coal Board has failed to make due allowance for the changing competitive position of coal. The industry, as a result, has been faced with a burden of depreciation and other fixed costs higher than the market warranted

In order to secure a better control over investment in future we consider that the Government should assume greater responsibility for identifying and examining more critically the vital assumptions on which the forecasts of yield on new investment are based and should equip itself technically to do this.'

Concerning the nature of this 'technical equipment', Fig. 1 illustrates in an elementary way the type of calculations required.^{39/}

FIG. 1: THE INTERACTION OF DEMANDS AND COSTS



The two components of this model are, in box A, a set of price-sensitive demand functions, and, in box B, a set of demand-sensitive cost functions. It is clear that an iterative calculation will result: if a set of fuel prices is assumed to begin with, the corresponding demands for each fuel can be calculated in box A; the way in which these demands are met in box B is determined by the technical and institutional structure of the supplying industries and implies a set of cost structures, and hence a new set of fuel prices, for use again in box A; and so on.

This process of calculation goes on the whole time in real life, but is complicated by many factors besides prices and technology:

individual preferences, public policies, foreign trade, geographical location and some of the many other cross-currents that influence both demand and supply. Thus, at any point in time, a certain set of preferences, based partly on past experience, partly on the appliances available and partly on prices, determines the pattern of demand on the part of users. As the months go by, new techniques are evolved by the producers, and new sources of fuels are discovered: new methods of generating electricity or of making town gas from light petroleum feed stocks, automated coalmining techniques, new sources of natural gas, crude petroleum with new characteristics from recently developed oil fields. The government changes its tax policy. New products become available from abroad. All these developments eventually make their impact on the users through changes in the prices of individual fuels, not only in relation to one another, but also in relation to the prices of other commodities. As a new pattern of fuel demand emerges, not only as a result of price changes but also as a result of the changing habits and tastes of consumers, its repercussions gradually have their effect on the pattern of supplies. And so on through the years and in all branches of economic life. The existence of this groping (*tâtonnement*) process is no recent discovery;³⁹⁷ the classic description of it was given by Walras nearly a hundred years ago:⁷⁷⁷

'Such is the continuous market, which is perpetually tending towards equilibrium without ever actually attaining it, because the market has no other way of approaching equilibrium except by groping, and, before the goal is reached, it has to renew its efforts and start-over again, all the basic data of the problem having changed in the meantime.'

The essence of a forecasting model is that it can coordinate the

'basic data', trace their past course and indicate their probable course in the future, and thus reduce the frustrating effects of ignorance and uncertainty. Given a set of definite aims, a model provides the 'technical equipment' for analysing the impact of economic and other changes on the system as a whole, for examining the outcome of alternative policies, and for estimating the sensitivity of individual and collective behaviour to alternative assumptions about the future.

4.2 The nature of the forecasting problem

4.2.1 The factors of change

Individual socio-economic systems continue to grow in size and complexity. There is thus an even greater need to understand the interrelations of their component parts and to anticipate so far as possible the future requirements which these growth tendencies impose.

As with other economic categories, the difficulties which underlie the forward estimating of energy needs arise particularly from the fact that socio-economic changes contain elements which to the observer appear to be of a stochastic or apparently random nature.⁷⁸ Development progresses uniquely from successive points or stages already uniquely determined, rather than along a trend that is a regular function of time. Moreover, in a completely unplanned economy, if foreknowledge were available at any point, it would tend to modify development from that point.

This, however, is only part of the truth. Some items of the total complex of interaction which generates the demand for energy may be regarded as possessing, over limited periods, a trend that is stable in the sense that fluctuations in rates of change occur only slowly.

Particularly in countries that are not centrally planned, another sector of the complex does remain largely unpredictable since it may fluctuate irregularly from one year to another, though within a certain probable range.⁷⁸⁷ It is thus possible to outline a descriptive model of the working, in such a case, of the different influences which affect energy supply and demand.

Such a descriptive model has three main types of component:

- a series of demographic, technological, economic and social tendencies which interact with one another to furnish a built-in growth mechanism that (at present) is more or less self-perpetuating in character;
- a series of economic and politically-influenced variables that are generated both nationally and within the international community and which fluctuate in an irregular manner;
- certain climatic factors - departures from average winter temperature and from average dry or wet hydraulic conditions - which fluctuate irregularly within a certain probable range.

The relative importance of these sets of tendencies is reflected in the order in which they are set out above.

(i) Self-perpetuating growth tendencies

In a modern, mature, industrial economy, population is commonly increasing by around one per cent, at present. The active population, or potential labour force, is often rising rather more slowly than this. Since means of communication, transport facilities and the dissemination of information are also expanding steadily, interaction between individuals and their exposure to intellectual stimulation and sources of new knowledge increase more rapidly than does the number of people.

Growth in technology and innovation is thus an exponential process.⁷⁸⁷ Productive techniques and equipment, and methods of

applying new knowledge to increase the volume and diversity of material goods and services, show an ever-continuing rise. This is possible only because average output per worker/hour employed can continue to increase as a result of growing mechanisation and improved economic organisation in a wide range of productive sectors. This rise in labour productivity is, nevertheless, very unevenly distributed.^{78/} While the mass-production of many goods - textiles, metal manufacturing etc., - has been achieved by spectacular advances in mechanisation, in other fields - mining, agriculture, and building construction, for example - where more hand labour is still required, the cost-reducing element is relatively less marked. Finally, in the case of various services, labour productivity has risen slower still and the element of hand-labour remains predominant.

Accompanying the self-generating process incorporated in the demand side of the modern economic system, there are thus slow structural changes at work in the productive sectors, though the latter require increasing amounts of inanimate energy to support a rising output of goods. In nearly all fields, more units of inanimate motive power, or of heat, light or chemical energy, are commonly required relative to each unit of labour employed, though (through growing efficiency in application) a slowly declining amount of energy may be consumed for each unit of final output.

These changes in the relative cost of supply may influence the growth of demand for different products. Moreover, the using-up of non-renewable natural resources, whether of raw materials or of inanimate energy, leads to other changes in the relative importance of different types of processing industry, including the energy-supply industries themselves. Slow progressive changes in the

demand for different forms of energy thus continue to be part of the process of contemporary economic change.

This self-generating process of potential economic evolution contains two further components.^{78/} The rise in social and intellectual interaction and the rise in material productivity in turn generate, when the basic necessities of life have become widely acquired, a continuing widening of horizons on the part of individuals. This leads, at present, to ever-rising expectations on the part of consumers. Moreover, capital expenditure on new equipment tends, in the short-run, to be a more or less irreversible process, in the sense that equipment, once installed, will tend to be employed. In the absence of irregular constraints and sources of fluctuation imposed by the second component in the descriptive model, the self-perpetuating impetus of contemporary industrial society would produce a series of smoothly-growing or smoothly-changing demands for different forms of energy, the rate of change differing according to the competitiveness of the energy source in question. These rates would in some cases decline slowly with time, as consumption per head increases.^{79/80/} "Elasticity coefficients", i.e. indices relating the change in energy consumption to changes in overall output or activity, would commonly be less than unity.^{78/81/}

(ii) Economic and associated sources of fluctuation

The extent to which this model of potential growth corresponds to the situation actually experienced differs from country to country according to various factors - including, inter alia, the endowment in basic natural resources and the consequent role of international trade.

Economic causes of fluctuations in overall output and demand, which in turn influence the demand for energy, may be due to a lack of balance arising between interrelated components of the evolving national economy, on the one hand; or to a more widespread international imbalance between separate national entities, on the other.

At the national level, a familiar example is the variable imbalance between rates of increase in wages and in output. Fluctuations in capital expenditure in key industrial sectors may also lead to a lack of coordinated development.

Differential development between distinct regions of a country or between different countries, international balance of payments difficulties, varying causes of fluctuation in the competitive international position of different industries - these are all among the phenomena of unbalanced development.

The counteracting activities of governments include adjustments in interest rates, taxation, import duties and restrictions, subsidies and limitations on public capital expenditure. In accordance with overall policy, these may at times be varied fairly widely and frequently so that little can be done to foresee such influences in detail. It is also notoriously difficult, except perhaps in particular cases, to forecast tendencies in international trade. Simple hypotheses, such as an extrapolation of the relationships between growth in total national output and growth in volume of international trade, are thus relied on in some forecasts when considering the future role of energy imports in a national economy.

Short term economic measures, of the type referred to above, may of course be introduced either to correct temporary imbalances within a national economy or to implement, say, an energy policy.

The former have had some success in helping to correct cyclical economic expansions and contractions of a classic form. The range of periodic variation in economic growth has been much reduced within the post-war period in countries that are not centrally planned. Nevertheless, such influences have a disturbing effect on the demand for energy through their influence on the cost of new capital investment, which may be required some years in advance of the demand to be met, as well as through temporarily reducing or artificially stimulating immediate industrial expansion and general economic growth plus the demand for new energy-using appliances by household consumers. Resistance of different forms of energy demand to temporary accelerations and restrictions of the market varies according to the form of energy, the nature of the supply industry, its cost structure and its characteristic price elasticity. These various questions of conjuncture and price are further discussed below.

(iii) Varying weather conditions

Year-to-year variations in average winter temperature at periods of peak demand occur as stochastic phenomena in time series of observations, and can be allowed for in any particular year in advance only on the basis of probability derived from experienced frequency. To the extent that rank-order distribution of varying values, established over a considerable period of years, is statistically a normal one, it is possible as a first step to plot modular coefficients (for example on a log scale) against their rank-order (on a probability scale) and to study the probability of successive levels of occurrence as an approach to a straight-line distribution. ^{78/}

4.2.2 Distinguishing between different causes of change in demand

In the post-war period at least, rates of growth in total national product, in industrial production and in labour productivity have been rapid and comparatively well-sustained in nearly all Western economies. Deviations from growth in national product, for example, have commonly been of the order of only $\pm$ a few per cent of the total. To this extent then, the self-perpetuating growth tendency, aided by improved economic planning and understanding, has of late tended to predominate over the stochastic element in demand.

How far do such considerations apply to the demand for energy? Here it is necessary to distinguish between factors which remain largely independent of fluctuations and those which are influenced by conjuncture and climate. A distinction has also to be made between situations of high and low conjuncture.

It is perhaps useful to consider separately the effects of the following influences:

- technical progress (and its differential effects encouraging substitution);
- the level of economic activity;
- policy measures affecting demand, price or future capital costs (taxes, interest-rate changes, import duties, etc.);
- market-induced or cost-induced price changes;
- progressive exhaustion of natural resources.

(i) Technical progress

This is seen in improved efficiency and reductions in capital and operating costs - for example, economies of scale due to larger generating units in thermal power stations, or improved steam conditions etc., leading to reduced fuel costs per kwh. It is also

seen in part in smoothly rising indices expressing changes in output relative to changes in labour employed. The overall effect on the demand for energy is reflected, at present, in a slow and comparatively smooth decline in the ratio of total primary energy input to total national product - a reflection of the fact that overall efficiency of application of energy is tending to rise. More and more secondary energy (particularly electricity) is being employed, both in the transformation of primary energy and in final energy use. Associated with these long-term trends are slow structural changes in composition of total energy supply, due to the differential cost-influencing effects of technical advance and differences in the adaptability of some forms of energy to types of use.^{82/}

(ii) Economic fluctuations

At this point, the influences of short-term economic fluctuations must be considered. It may be noted that the rise in an index reflecting overall efficiency of energy use (in other words, a decline in energy "intensity") sometimes tends to accelerate during downturns in economic activity.^{78/} This is probably because output may at such times be concentrated in the most efficient plant and scrapping of obsolete plant may be stepped up. There is also the point that some energy-intensive industries (such as iron and steel) may fare badly at such a time.

This leads to two further points. First, temporary upswings and downswings in the economic climate often have different effects on different forms of energy supply. Demand for electricity, for example, contains a component that is directly attributable to the rate of industrial output and another that reflects the continuing growth in

electrification. In forms of energy supply that are not expanding, the influence of downswings is therefore much more direct.

The second point is that some energy-consuming sectors are more influenced than others by economic fluctuations. This is because output of certain industries such as, for example, iron and steel and construction industry materials, are disproportionately heavy users of energy and are geared to the supply of capital goods. Similarly, transport needs for coal and electricity (as opposed to petrol for road vehicles) are closely proportionate to industrial activity. Household requirements, particularly for electricity, tend to show great buoyancy during downturn periods and possess enormous growth potential.⁷⁸⁷

It is thus often possible to separate the sectors of energy demand which generate growth potential and resistance to fluctuation from those where substitution and the influence of competition in price per Btu are more in evidence, or where demand remains largely proportionate to output. Analysis of the composition of production and energy use, and of the range of influence of purely economic fluctuations, are necessary to elucidate the factors involved.

(iii) Policy considerations

Particularly if central economic planning is not in force, comparatively less can usually be done to anticipate the governmental policy factor. To work out the influence of economic growth and labour productivity, on the one hand, and of factors of cost-reducing technical progress and natural resource exhaustion, on the other, requires a confrontation of extrapolated tendencies, in these various fields, based on a careful analysis. If this can be

done, the role of energy imports that may or may not be avoidable can, for instance, be broadly evaluated. Partially non-economic factors - social investment or regional development considerations, for instance - might also play a part. The differential role of substitution - promoting technical progress or economies of scale in different forms of energy supply may, to some extent, be a subject on which enlightened assumptions for the medium-term future can be made from coordinated study, particularly if careful energy resource surveys are made and corrected periodically.^{83/}

(iv) Price changes

With regard to the difficult question of allowing for purely market-induced or intrinsically cost-induced price changes of energy, an approach somewhat similar to that governing the study of policy influences may, in principle, be of some use. Here also judgement and experience must come into play. The scale of the energy supply industry concerned; the existence of a multiplicity of products or qualities; their replaceability or near-monopoly; and the differences in price elasticity between forms of energy - all these must be allowed for as well as the long-term influence of technical progress and resource limitations. In relation to likely price changes, these latter considerations - in the coal industry, for instance - are sometimes studied in terms of the probable evolution of wage-rates, productivity, capital expenditure, depreciation, financial changes and import or export trends.

The adaptability of selling prices and tariffs in the face of conjunctural or operational fluctuations varies greatly as between different forms of energy supply. This is due to the

varying part played by labour costs, as opposed to those, say, for research and development. A labour-intensive industry is less free to reduce prices to stimulate demand than one which is more elastic in its cost-allocations and structure. The petroleum industry, which is widely international in its market, highly diversified in its products, and in which freight rates, research and exploration play an important part, is, for example, comparatively well placed to adjust supplies and prices to market conditions.

With these various considerations in mind, energy projections in some countries attempt alternative forecasts for coal requirements or for the key relationship between coal and oil requirements, these being based on different combinations of mainly long-term price-influencing assumptions - those covering wages, productivity, taxes, imports etc. Thus for Western Germany, as an example, three different combinations have been used for coal needs in 1975, two of them with alternatives using present salaries and 1975 prices or 1975 salaries and prices respectively.⁷⁸⁷ The three combinations include alternatives of no tax, or two different specific tax levels, on imported coal. The corresponding production number of miners and average productivity are calculated according to the different assumptions used. Other alternative assumptions have been made for light and heavy fuel oils, key relationships considered throughout being those between coal and fuel oil and between internal and imported coal supplies.⁷⁸⁷

All such analyses have to pay full attention to the weighting to be assigned to security. As in the examples cited, it should be clearly established whether what is sought is an overall

optimum for the conditions given, social and other benefits and costs being taken into account; or whether the comparison aims purely at a projection of the likely interplay of market and technical substitution forces.

(v) Exploitation of natural resources

The degree of exploitation of renewable energy resources such as are offered by water power, or the extent of expected exhaustion of fuel reserves are important factors in deciding the long-term rhythm and perspective of development for particular forms of energy. Replacement of one source by another, or by imports, is inevitably linked with the future "life-expectancy" of different sources of supply. Limits to economic production from available sources and to useful capital investment for the future, may depend on the cost-reducing prospects opened up by technical progress - for example, in project design, equipment and methods of operation. Capital charges are influenced by changing interest rates. Careful surveys, based on a common methodology and repeated periodically, can therefore throw much light on the future development perspective for certain forms of energy, but they cannot remove all uncertainty stemming from this source.

According to the stage reached in the using-up of a particular energy reserve, there is often a characteristic acceleration and slowing-down process at work. In the earlier stages of exploitation, consumption may (as has been found overseas in the case of natural gas) be limited mainly by production possibilities; whereas, during the period when more than half the probable economic potential has been used up, there is likely to be a slowly declining rate of

development as reserves become more and more costly. This allows too for a smooth transition from one energy source (or source of supply) to another. Examples could also be given of the holding-up of exploitation of certain types of resource, until the point is reached at which an alternative form of energy has reached the stage at which it cannot satisfy all requirements.^{78/} It is clear that the whole question of a country's natural resource endowment is central to the problems of forward planning and forecasting.

4.3 Methods of projection

Methods of projection available for forecasting in any economic sector are basically limited in number. Those available for energy forecasting do not differ in their essentials from methods used for dealing with certain other economic categories - in estimating steel consumption or future traffic density, for example. In the case of energy requirements, forecasts are frequently made more or less separately for individual forms of energy, though the fact that these forms may in part be replaced by each other implies the need for a common approach.

The main special problem which arises when the latter course is, in fact, followed lies in the need to reconcile the estimates for different forms of energy and different consuming sectors, so as to arrive at a result that is both internally consistent and sensitive to an interplay of technical and economic influences, the effects of which vary from one sector to another. It is, therefore, necessary to distinguish between the methods of forecasting themselves and the ways in which they may be applied to achieve a harmonious result.

The main types of energy planning, or projection, employed in different countries of the world, in varying circumstances, may be divided into four groups;

- (i) direct extrapolation of the rate of change of requirements for different forms of energy, based on past trends;
- (ii) extrapolation based on the observed relationship between energy used and one or more economic variables;
- (iii) determination of the total energy requirements on the basis of planned production and specific energy consumption per unit product in different industries. This is particularly applicable in countries which undertake comprehensive economic planning;
- (iv) forecasts based on comparative analysis of homologous trends in different countries at various stages of economic development.

These four types of projection do not necessarily exclude one another completely. They may also be combined when, for example, separate regional projections are brought together and compared with national forecasts prepared on a different basis. All methods are thus available as alternatives, so as to obtain either a check or a compromise result. They all reduce to some logically consistent mode of extrapolation offered by observed regularities in past behaviour and, properly used, should be adequately underpinned by judgment based on experience. The assumptions made may allow for a continuance of the mode of evolution of the factors operating to produce change; or, by the use of adjustments or ranges, provision may be made for the unanalysed interplay of various economic and technical forces. Despite their common features, these methods of projection necessarily differ widely in their application and in their use in relation to different forms of energy. It will be convenient to compare some of their main features.

4.3.1 Direct extrapolation on the basis of observed characteristics of a past trend

This type of procedure is widely used where short-term projections, for up to one or two years ahead as a maximum, are required for operational purposes (as with electricity or gas) or for summing up market trends (as with coal or petroleum demand). Direct extrapolation may equally be used for medium - or long-term projection, as is done in Finland, for example.^{78/} In this case, two distinct varieties may be envisaged. On the one hand, there is the familiar extrapolation using a rate of change deduced from past changes in statistical data. If the assumed mode of change is exponential - i.e., increasing at a constant percentage rate per unit of time - one has the type of growth particularly characteristic of electric power consumption in recent years and of certain other forms of activity, including energy demand at times of rapid expansion. For an enumeration of some basic types of formulae involved, see Appendix II at the back of this book.

It may, however, be equally possible to deduce some other evolution expressed by a mathematical formula which fits development in the past and is assumed (with regular checking or revision) to characterise its likely changes in future. Such a formula has been applied^{78/} to express a postulated slow decline in future rates of growth in the world's total electricity consumption.¹⁾ To the same general class of mathematical

1) This formula is an empirical expression for a slowing down in growth that is a function of time, i.e. consumption in

$$10^9 \text{ kwh} = 1130 \left(\frac{t - 1875}{77} \right)^{4.3},$$

where t = the year for which consumption is required. A similar formula to that of the world has been derived experimentally for the United Kingdom as follows:^{78/}

$$10^9 \text{ kwh} = 58.8 \left(\frac{t - 1878}{74} \right)^{4.92}$$

extrapolation belongs the attempt to fit to past developments in statistical series an "S-curve" of development derived from expressions similar to that governing a logistic trend, i.e. one which accelerates to a "point of inflexion", beyond which growth declines slowly and is asymptotic. The essential difficulties in applying this latter type of approach are that it is not often possible to determine in advance a point of inflexion which can apply to the future trend with any assurance, and there is no certainty that fresh logistic surges will not later be superimposed on the existing one. The S-curve may perhaps be used with somewhat greater assurance in analysing such questions as the percentage composition of the total primary energy supply - for example, the percentage role of coal and oil in industrial fuel requirements.

It is evident that the longer the statistical series are available for the past, the more confidence is likely to be felt in any projection based on direct extrapolation. To this end, some countries follow the useful practice of issuing regularly an ever-lengthening time series of basic data which may be used as standard for comparative purposes. This is the case, for example, in the United States, where a sixty year series for consumption of each commercial source of energy is circulated in the Weekly Coal Report issued by the Department of the Interior.⁷⁸

4.3.2 Extrapolation from observed relationships

Although it has many variants, this mode of projection offers a distinct and widely used extrapolation method. Its use may depend on the prior existence of a forecast for certain other economic variables, with which the development of energy requirements has been found to be associated. From the nature of the method, projections tend to be made for certain selected years, rather than as a continuous series.

In principle, the method may be applied to any type of energy demand series.

Study of many types of associative formulae in different fields show that such economic indicators as the following are of the type most frequently incorporated:^{78/}

Demographic data:

Total population or economically active population.
Total labour force.
Employment in industry.
Hours of work.

Global economic series: National product or national income.

Industrial production.
Manufacturing production.
Fixed capital formation (total or per sector).

Economic categories:

Steel consumption.
Agricultural production indices.
Housing construction indices.
Sepcific rail freight or passenger indices.
Road transport indices.

The statistical association employed to link the various energy categories with those of the above type include simple or multiple regression equations, expressing linear or non-linear relationships; simple coefficients representing the effect of a unit change in one variable on another ("elasticity coefficients"); and various empirical formulae.^{78/} Some main types of formulae involved are discussed in Appendix II.

Empirical formulae are extensively used to project future growth in total energy consumption (usually in coal equivalent), as a global control on more detailed forecasts for different consuming sectors and forms of energy. This procedure, which most commonly relates consumption to

national product, is followed, for example, in France, and it is also employed for the same purpose in various centrally planned economies such as those of Poland and Rumania.¹²⁷ Empirical expressions have been extensively used in preparing comprehensive energy projections for Belgium.⁷⁸⁷ In Canada, two alternatives of the method are employed to project future energy requirements, using gross national product and employment respectively.⁷⁸⁷ This approach has been successfully applied in the case of South Africa also, using the gross domestic product as explanatory variable.¹⁹⁷

It is, however, in the detailed econometric model that this type of method finds its most complete expression. Such models attempt to allow for some of the main influences at work in determining the development of energy requirements within the economy. They may be employed for long-term or short-term projections of energy needs.⁷⁸⁷ In principle, they can utilize relationships, the parameters of which are derived from regression analysis, to determine, for distinct forms of energy in each main consuming sector, the requirements as related to growth in population, general economic indicators such as national product, price indices, etc. Conversion efficiency and final end-use efficiency may to some degree be broadly allowed for. The method of using an econometric model thus requires the construction of a series of expressions covering relationships between the different energy categories, and also between certain of these and growth in the economy. The estimates may be prepared in successive stages. Since such models are essentially static, it requires fairly frequent amendment in the light of experience derived from its use.⁷⁸⁷

The advantages of using econometric techniques in energy forecasting were first recognised in the Netherlands, where Middelhoek²⁰⁷ did

valuable pioneer work. In recent years, however, the approach is increasingly favoured in other countries of the world and examples of such models, constructed for individual countries, are well documented. A detailed energy model for the United States of America, constructed by Morrison and Readling^{40/}, was recently published. In the United Kingdom, work is in progress on the construction of two independent models on the British energy economy, the first under the supervision of Professor Stone at Cambridge^{39/} and the second by the Ministry of Power.^{88/}

During the last World Power Conference, held in Tokyo, Japan, in 1966, considerable attention was given to energy forecasting and to the use of the econometric model, particularly, as an approach to the problem. With regard to industrial electricity demand, Edwards^{89/} (United Kingdom) presented a model incorporating not only a production index but also lagged variables and electric power prices. Bauer^{90/} (Austria) also presented a similar model. Takai^{86/} (Japan) indicated the relationship between the demand for electric power and gross national product in his country. Pavlíček^{91/} (Czechoslovakia) touched on the demand for energy as a function of gross national product, temperature and time. Vogely and Morrison^{15/} presented the results of a correlation analysis of each energy sector in the United States. In addition to regression analysis, Dobrzańska^{92/} (Poland) used the Leontief model, which provides a link between macro-economic and micro-economic considerations in energy forecasting. Laigroz and Lacoste^{93/} (France) analysed the shift in the demand for domestic appliances by using the stochastic Markovien process model. The observation repeatedly made was that the development of the econometric technique owes much to the recent development of the electronic computer.^{92/94/}

4.3.3 Forecasts based on planned output in individual economic sectors and the specific energy needs per unit of output

The methods so far discussed are adapted mainly for the construction of global forecasts, in which different forms of energy (usually primary forms) are combined and expressed in common units; or for the preparation of separate estimates for the use of particular types of energy supply in certain consuming sectors. Methods of projection, which by definition seek to cover the entire field of energy supply and requirements for a given economic system, must be determined comprehensively, so that the amounts of each form of primary and secondary energy required by the different consuming sectors are mutually consistent and in line with the expected trends in conversion efficiency and substitution. Moreover, such estimates should ideally allow for the effect of technical advances and social developments which may initiate structural changes in the growth of industries and other consuming sectors.

Plans and projections which adopt a comprehensive approach in respect of energy needs include the one-year, five-year and long-term or perspective plans of centrally directed economies; certain medium-term projections prepared as parts of comprehensive plans in certain other countries, such as France and Portugal, which possess an important private sector; and some comprehensive surveys of future energy needs prepared in countries lacking any overall economic programme.^{78/} These surveys normally proceed on the basis of the aggregate of a large number of separate sector estimates or market enquiries carried out for different energy supply industries, these normally being built up from, or reconciled with, separate local or regional estimates which take into account industrial or other developments in different parts of the country concerned. The method of approach, therefore, replaces reliance on the relative assurance of an economic plan by a use of overall economic forecasting

combined with the aggregate of a large number of separate regional and sectoral plans and estimates for energy needs which seek to anticipate the development of the market economy.

In all cases, extrapolation methods are employed as a control on the longer-term projections. In fully-planned countries of Eastern Europe this is commonly done by deriving formulae or coefficients covering relationships over the last decade between national product or industrial output and total energy requirements expressed in coal equivalent.^{78/}

The method that forms the basis of the centrally directed economic plan is that of establishing requirements for different forms of energy in the principal industries and consuming sectors by applying to planned levels of output and activity the specific energy needs of each type required to achieve those levels. Availability of adequate supplies is provided through coordinated analysis and research to determine:

- location of industries and energy supply;
- availability of unused energy resources;
- changes in efficiency of energy transformation, transport and end-use;
- trends in productive techniques and technical advances in different forms of energy supply;
- trends in productivity and energy use per worker and per unit of product.

Study of the probable interplay of factors causing substitution between energy sources, which is an important feature of comprehensive energy projections in unplanned or incompletely planned economies, is, in those which are centrally directed, thus partly replaced by an organised study of developing trends in different forms of energy, in respect of their relative economy and technical efficiency.

In all countries, however, long-term development of technology and structural economic change pose problems which cannot at any time be completely forecast. The method of economic planning outlined above takes this problem into account, in three ways. Firstly, parallel one-year, five-year and long-term or perspective plans are drawn up with decreasing degrees of detail. Plans of the third type are controlled by global projections and, in some cases, are prepared initially, allowing for alternative developments for certain projects. Finally, the formulations of energy needs are necessarily arrived at in stages, since they are mainly derived from the output plans, though the two aspects of planning proceed simultaneously and are interrelated.

In countries such as Bulgaria, Czechoslovakia, Hungary, Poland, Rumania and the U.S.S.R., comprehensive energy plans of the above type are drawn up with the aid of energy balances.⁷⁸ In some of these countries, and also in the Netherlands,⁹⁵ increasing attention is being given to input-output studies of the Leontief⁹⁶ type - i.e. matrix tables showing transfers to all the main economic sectors from each other in terms of value. These Leontief input-output models, which in varying detail have now been prepared for over twenty countries, seem, however, to offer comparatively little direct advantage for energy forecasting, although they may be adapted to throw light on the implications of structural changes in energy demand.⁷⁸

4.3.4 Forecasts based on comparative analysis of homologous trends in different countries

As in the case of the method discussed previously, the comparative method is a distinct approach, rather than a specific technique of forecasting. Although in simple form it is used fairly widely as an adjunct to forecasting, it is by far the least well understood and documented of

methods of projection, since its full use adds to the normal assumptions and uncertainties concerning the nature of long-term economic development.^{78/}

Comparison between trends in different countries can be based on the idea of direct extrapolation (Section 4.3.1), or can be based on extrapolation from observed relationships (Section 4.3.2). Where a particular energy category exhibits a fairly consistent type of development in many different countries over a long period it is possible to compare:^{78/}

- long-term changes in growth rates for single countries;
- short-term growth rates in different countries at the same time;
- growth tendencies in countries at widely different levels of specific consumption.

In this way it is customary, in preparing a forecast, to study those of other countries of similar economic structure, including those where per capita consumption is already at a much higher level.

Since expressions giving, first, an accelerating and then a declining growth on the model of the logistic curve are observed to fit trends in many economic phenomena, hypotheses governing future changes in growth rates are sometimes based on observed relationships between rate of growth and per capita consumption.^{78/} Within the steel industry, correlations between consumption per head and its rate of increase in many different countries are found to be a useful and significant aid in forecasting. A similar type of comparison has been made for electric power consumption in terms of ten-year rates of increase in many countries of the world. This has shown that while various countries, where consumption is at an initial stage (50-100 kwh per capita), have increased their demand by around fifty per cent during the period, the increase rose to 200 per cent or more in those where consumption approached the world average (750 kwh per capita) and declined

thereafter roughly in inverse proportion to per capita consumption.^{78/}

Felix has essentially reached the same conclusions by using analogous reasoning. In his approach to the subject he has studied data collected for 153 countries over a five year period from 1956-61 and evolved median curves of growth of per capita use of electricity versus population growth.^{85/} Straszacker^{55/} further adapted the approach of Felix and his resultant long-term forecasts of electricity generation in South Africa has of late been the most authoritative contribution on the subject in this country.

Felix, particularly, is an ardent disciple of the comparative technique and has indicated that the method can also be applied to the making of global energy forecasts.^{79/} In doing so, he calculated the yearly increase in the use of energy of all kinds in all countries over the years and showed how countries are ranked in per capita use of energy, on a smooth (log scale) curve. From this curve, he states, the relative industrial output, state of development, and, to some extent, even the growth prospects of any nation, can be determined. It is thus even possible to derive, from the curve, the time lags in development between different countries. On the basis of this curve, for instance, it is found that the U.S.S.R. lags about 58 years behind the United States. Rostow^{97/} strikingly parallels this part of Felix's thesis. He printed a chart indicating that in 1955, on an output - per-capita basis, the median lag between the United States and Russia - based on a study of 37 industries - was 56 years of growth.^{79/} The observations of Rostow not only lend credence to Felix's forecast, but in inferring a 56 year lag from a study of 37 industries where Felix finds a 58 year one by studying energy use alone, they also appear to vindicate Felix's faith in energy as the sole yardstick of industrial output.

Comparative methods offer considerable potential scope for forecasting purposes. In a relatively simple form, the comparative approach is used already in certain countries, such as Austria and France.^{78/} Its value is implied in the emphasis given to international comparability in various surveys of the energy situation. Nevertheless, no full-scale and detailed analysis has yet been completed in this field so far as forecasting is concerned.^{78/}

Not all aspects of the energy supply situation are suited to comparative treatment in respect of forecasting. From this point of view, one may classify types of series which are particularly likely to repay study as follows:

- those which follow an analogous type of development, even in countries which differ significantly in relative levels of capital investment, exports, national product, etc.,
- those of which relationships with forms of energy consumption evolve consistently in time as the latter develops.

On the other hand, characteristics which vary with the structure of national resources and resulting pattern of industry in different countries, rather than with their levels of consumption, are less likely to yield useful results except where their structural features can be matched.

CHAPTER 5

A FORECAST OF THE ENERGY ECONOMY OF SOUTH AFRICA

5.1 Introduction

It is evident that in medium - and long - term projections an element of judgment must play a considerable part. Inherent in any extrapolated projection from past data is the idea (not always explicitly recognised) that a group of residual factors taken together will continue to operate in the future as they have done in the past. This may be true to the extent that some fluctuations offset one another; but it is mainly the element of uncertainty due to influences largely external to a country - and also to short-term policy decisions taken to counteract their effect - that produces the stochastic element in present demand tendencies. Broadly speaking, this stochastic, or "random", component tends at present to be overshadowed by strong forces working towards continued growth, of which international competition is by no means the least. The discussion in Chapter 4 has outlined briefly some of the ways in which part of the residue of intangible factors can be studied and perhaps reduced.

If a total national requirement for energy at a given point in time is taken as known, it may or may not be assumed that it is possible - in theory at least - to define an optimum combination of the forms of energy and means of supply available to satisfy that requirement. How far is it implied here that all outputs of goods and services are finally known? How far are non-quantitative variables allowed for? Such questions are likely to crystallise differences of opinion regarding the nature and possibilities of the planning or forecasting process.

In one sense, therefore, the concept of energy forecasting invites the risk of a question-begging fallacy. The combination of different sources of heat, light, motive power and chemical energy developed within a country depends on its unique endowment of natural resources of primary energy, and on conditions for any supplementary imports that may be required. In turn, this structure of actual and potential supply encourages, mainly through differential unit costs, particular types of industries and particular demand patterns in households and transport. Not only the pattern of energy supply at a given time, but also the future interrelated development of certain resources, may depend on the special technical and economic characteristics of the particular forms of energy available within the country concerned. At best, therefore, the only contribution that can be made is to indicate what the likely outcomes will be, given a series of reasoned assumptions. These assumptions will be the subject of the next Section.

Most other developed countries vary widely in their degree of industrialization, in their possession of diversified natural energy reserves, in mode of economic organisation, and in their levels of income and energy use, as expressed by average consumption per head. Characteristic rates of growth in energy consumption vary correspondingly.

Nevertheless, in the post-war period, economic growth has continued at a steady and rapid pace in nearly all developed countries. Study of the main trends of interest for forecasting, and of the ways in which those affecting the energy economy are related to it and to each other, shows that certain relationships are essentially similar in kind in nearly every country, despite the fact that the rates of change themselves vary, as also do the industrial and income structures which generate them.

These relationships are particularly important in making projections, notably the fact that in most developed countries certain basic long-term series may normally be arranged in the following decreasing order of average growth rate:¹⁾78/

- total electric energy consumption;
- industrial electric energy consumption;
- manufacturing production;
- total national product;
- commercial energy consumption (in common units);
- housing construction;
- agricultural production;
- population;
- economically active population.

The greater the similarity in these rates of growth the slower will be the change in any of the indices expressing ratios between them.

From the foregoing, it follows that various important ratios or specific values also possess common features in different countries, ie. those such as:

- commercial energy consumption per unit of national product;
- consumption of energy per industrial worker;
- productivity per man-hour in industry;
- energy consumption per unit of product in different industry groups and in agriculture;
- relative use of electricity and total energy.

These and many other economic indices which evolve fairly regularly provide the basis both for individual projections and for comparative

1) This is of course not immutable, but refers to recent conditions in many countries.

studies of future requirements. Where direct extrapolation methods are not used, extrapolation from relationships may be employed by the construction of regression equations or by applying growth-rates for specific needs in energy to forecasts of the volume of output or activity. These methods may also be applied in forecasting aggregates, where many different types of projection are combined and the final results reconciled.

It is pertinent to consider the analogy between energy forecasting and the making of plans and projections for the economy as a whole. Apart from the preparation of centrally directed economic plans where econometric models are used, overall projections for medium or long-term changes in total national product are usually made in the form of global projections rather than by adding up sectoral forecasts. The latter method may, however, be used in planning total investment.

In its expansion over the past two decades the South African economy has required progressively greater amounts of energy. Not only has total energy demand increased at a high rate, but major shifts have occurred in the mix of energy resources supplied to consuming sectors. The pattern of flow of energy within the economy is an ever-changing one. Technological and other factors that influence the size and structure of the country's energy markets have created a very different pattern of energy consumption in 1968 than that which prevailed in 1910.

In this study, the evolution of energy as an input to the economy was examined historically up to 1968, the latest year for which data are available. In this Chapter, hypotheses concerning changes that have taken place are advanced and a forward look is taken at the probable patterns of energy consumption in the years 1980, 1990 and 2000. Consistent with the approach discussed in Chapter 3, this will be done in two phases. The first

phase is the forecasting of the demand for energy in major energy markets or consuming sectors, and in the second, an attempt will be made to indicate the optimum combination of the forms of energy and means of supply consistent with satisfying that demand.

5.2 The assumptions on which the forecast is based

It is necessary to observe that the forecasts outlined in the following paragraphs presuppose the following basic environmental assumptions:

- (i) Socio-political assumptions. It is assumed that the current socio-political structure of the South African society will be perpetuated and that the current status quo will continue throughout the forecast period under review, with the exception, possibly, of minor evolutionary modifications.
- (ii) Economic assumptions. It is assumed that present and future governments in South Africa will remain dedicated to the free enterprise system with no significant interference in the operation of the free present-day capitalist economy.

It is further assumed that the rapid growth which has characterised the economy over the last number of years will continue into the future, that the tendency towards increased industrialisation will remain so that the contribution of the industrial sector will continue to play an ever growing part in the evolving economy. In quantitative terms, it is expected that future economic growth will be equivalent to an average annual increase of $5\frac{1}{2}$ per cent in the real gross domestic product, which is in accordance with the recent and current targets of the country's Economic Development Programme. ^{98/}

Lastly, it is expected that the mining sector will continue to make important contributions to the economy of the country generally, and to the balance of payments specifically. Although no sudden substantial increase in the official price of gold is contemplated, it is, nevertheless, expected that the free market price of the metal will continue to rise slowly, enabling the economic exploitation of the country's unmined gold reserves. It is, therefore, expected that the balance of payments will not be a factor limiting uninterrupted future economic growth.

- (iii) Energy assumptions. On the supply side, no local exploitation of crude oil or natural gas is assumed. This assumption obviously has to be made in the context of this study, in view of the uncertainties surrounding the success of the current exploratory programme, as well as the far-reaching implications for the energy economy if such exploitation does eventuate. If, however, significant quantities of crude oil or natural gas are found, it is not expected that it will affect the demand forecast materially. The impact will of course be relatively significant on the supply side of the model.

Lastly, in view of the problems associated with technological forecasting, it is assumed that no drastic technological revolution will take place over the forecast period. This aspect will be dealt with more fully in the discussion on the supply component of the forecast.

5.3 The demand component

In one sense, it may be said that the underlying factors, or human needs, causing, or generating, the demand for energy in various consumption categories are independent of the sources of energy supplying those needs. The demand for energy in the domestic sector, for instance, is the outcome of the need of domestic consumers to provide heat for cooking or space heating, and to satisfy their demands for lighting and mechanical power. Similarly, energy consumed in the transport sector is the result of satisfying the transport needs of people. The supply structure of the energy economy, which has gradually developed to satisfy these energy needs, is dependent on the unique characteristics prevailing in a country, such as its endowment with natural resources, state of development, etc.

In order to forecast the spectrum of future energy demands, it is therefore necessary to quantify, as far as possible, these causal factors, or needs, underlying the demand for energy in different consumption categories.

5.3.1 Sectoral models

The approach used in this study was to make a survey of all the explanatory or exogenous variables, for each typical consumption sector, used in other studies of this nature, and to augment these with variables considered representative of local conditions and, finally, to examine these in the light of availability of data. For each consumption sector, all the alternative series available were then correlated with the series on useful energy consumption for a particular consumption sector and the resulting relationships examined. In selecting the relationships which were finally used, the usual selection criteria

applied, such as the nature and quality of the historical relationship and the ability or otherwise to forecast the explanatory variable, etc.

In this respect, it was observed that most of the demand models available in the literature are really logarithmic regression functions. The advantage of functions of this nature is that the calculated regression coefficients can immediately be interpreted as elasticity coefficients.⁹⁹⁷ Semi-log and double-log variants of the alternative relationships were therefore also examined. It was, however, generally found that these logarithmic equations yield inconsistent results, in that forecasts based on them tended to sweep away towards unrealistic levels, especially over the longer forecast periods.

5.3.1.1 Households sector

Determining variables normally employed to forecast the demand for energy in the households sector include:

- population
- economic growth
- standard of living
- private consumption expenditure
- disposable income
- expenditure on durable goods
- temperature, and
- relative prices of different energy sources.

In the case of South Africa, it was found that two variables, per capita real gross domestic product and real private consumption expenditure, explain the variation in total useful energy consumed in this sector very well.

For this analysis, economic data are required. Table 46 provides the economic data which were used in the construction of the sectoral relationships and control forecasts. Sources of data used in respect of each individual series will be discussed in the applicable sector.

The series on the real gross domestic product (GDP), Table 46, Column (1), were taken over from Kotze (1967)¹⁹⁷ and brought up to date with the latest estimates provided by the Reserve Bank Quarterly Bulletin.¹⁰⁰⁷ The earlier statistics of the series were constructed¹⁹⁷ from sources published by Groenewald,¹⁰¹⁷ Stadler¹⁰²⁷ and Du Piesanie.¹⁰³⁷

The series on real private consumption expenditure were obtained from Groenewald and Kock¹⁰⁴⁷ and further brought up to date with statistics quoted in various Reserve Bank Quarterly Bulletins. Per capita real GDP statistics were calculated from statistics on the total population, already discussed in Table 33 (page 190), and the real GDP as supplied in the first column of Table 46.

Figure 2 provides the scatter diagram of useful energy consumption in the households sector (column (8), Table 36) and real private consumption expenditure (column 3, Table 46). A very satisfactory relationship between the two variables is evident. A linear regression model was subsequently fitted to the observations by applying the method of least squares¹⁰⁵⁷ which yielded the following equation, with a coefficient of correlation of 0.99:

$$\begin{aligned} Y &= 2017.5 + 10.7368X, \text{ where} \\ Y &= \text{energy consumption in households} \\ X &= \text{real private consumption expenditure} \end{aligned}$$

In the same manner, the scatter diagram of per capita energy consumption in households and per capita real GDP is indicated in Fig. 3. The calculated linear regression yields a correlation coefficient also of 0.99 and the resulting equation is:

TABLE 46: ECONOMIC SERIES

YEAR	REAL G.D.P.	REAL G.D.P. PER CAPITA	REAL PRIVATE CONSUMPTION EXPENDITURE	GROSS VALUE OF MANUPAC- TURING OUTPUT	CONSUMER PRICE INDEX	REAL VALUE OF MANUFACTURING OUTPUT (GROSS)	REAL VALUE OF MINING AND QUARRYING CONTRIBUTION TO G.D.P.	MINING PRODUCTION	RAILWAY TON MILES	STEEL PRODUCTION
	(1958 PRICES) (R m) (1)	(1958 PRICES) (R) (2)	(1958 PRICES) (R m) (3)	(CURRENT PRICES) (R m) (4)	(OCT. 1958 = 100) (5)	(1958 PRICES) (6)	(1958 PRICES) (R m) (7)	('000 TONS) (8)	(MILLIONS) (9)	('000 TONS) (10)
1933	1,263	139		137	42.2	322	218	12,352	5,380	
1934	1,526	165		168	42.7	390	211	14,258	5,338	
1935	1,616	171		194	42.5	453	222	15,949	7,160	
1936	1,792	186		221	42.7	513	236	19,109	7,368	
1937	1,958	200		257	43.7	583	256	20,281	9,076	
1938	1,936	194		273	45.2	599	265	21,743	8,414	
1939	2,085	205		286	45.2	628	275	22,088	9,349	
1940	2,176	210		329	46.8	697	291	23,133	9,850	
1941	2,307	219		387	48.9	785	297	24,267	10,267	
1942	2,309	215		432	53.1	807	296	26,209	10,615	
1943	2,402	220		470	56.3	828	270	26,311	10,930	
1944	2,450	221		545	57.9	934	267	29,360	11,768	
1945	2,552	227		619	59.8	1,027	270	30,139	11,951	
1946	2,643	231	1,834	681	60.7	1,113	270	30,672	12,395	
1947	2,770	237	2,115	795	63.2	1,248	262	31,215	12,949	
1948	2,991	250	2,259	939	66.8	1,394	282	32,107	13,752	
1949	3,068	251	2,332	1,082	69.3	1,549	306	34,451	14,845	
1950	3,246	261	2,410	1,239	72.0	1,707	323	36,590	15,826	
1951	3,420	269	2,463	1,612	77.3	2,069	332	37,867	16,694	
1952	3,530	271	2,509	1,842	84.1	2,173	344	40,826	17,765	1,326
1953	3,704	277	2,634	1,943	87.0	2,215	343	41,731	18,256	1,368
1954	3,946	288	2,739	2,050	88.6	2,295	391	42,415	18,580	1,518
1955	4,154	295	2,844	2,261	91.4	2,454	438	46,740	19,862	1,681
1956	4,375	303	2,935	2,343	93.1	2,497	484	48,522	20,320	1,708
1957	4,568	309	3,068	2,467	95.9	2,552	536	50,111	21,122	1,850
1958	4,679	309	3,170	2,603	99.2	2,603	545	53,791	21,973	1,952
1959	4,897	315	3,227	2,657	100.4	2,625	610	53,565	22,767	2,026
1960	5,139	323	3,332	2,784	101.8	2,713	658	58,063	24,262	2,278
1961	5,351	329	3,382	3,019	103.7	2,888	697	60,525	25,248	2,678
1962	5,663	340	3,523	3,197	105.3	3,012	750	62,848	26,685	2,842
1963	6,140	360	3,761	3,511	106.5	3,270	788	64,834	28,359	3,032
1964	6,587	377	4,126	4,067	109.2	3,725	838	69,996	29,988	3,310
1965	6,911	387	4,337	4,861	113.2	4,260	867	72,450	32,369	3,450
1966	7,257	397	4,570	5,285	117.3	4,469	903	76,777	32,757	3,639
1967	7,837	418	4,749	5,707	121.2	4,671	934	77,045	34,632	4,135
1968	8,114	423	5,118	6,108	123.3	4,914	995	80,792	36,958	4,476

FIGURE 2: ENERGY IN HOUSEHOLDS VERSUS REAL PRIVATE CONSUMPTION EXPENDITURE, 1946 - 1968

$$\bar{Y} = 2017.5 + 10.7368X$$

Y = HOUSEHOLD
ENERGY
CONSUMPTION

(10⁶ MEGAJOULES)

50,000

30,000

10,000

1,000

3,000

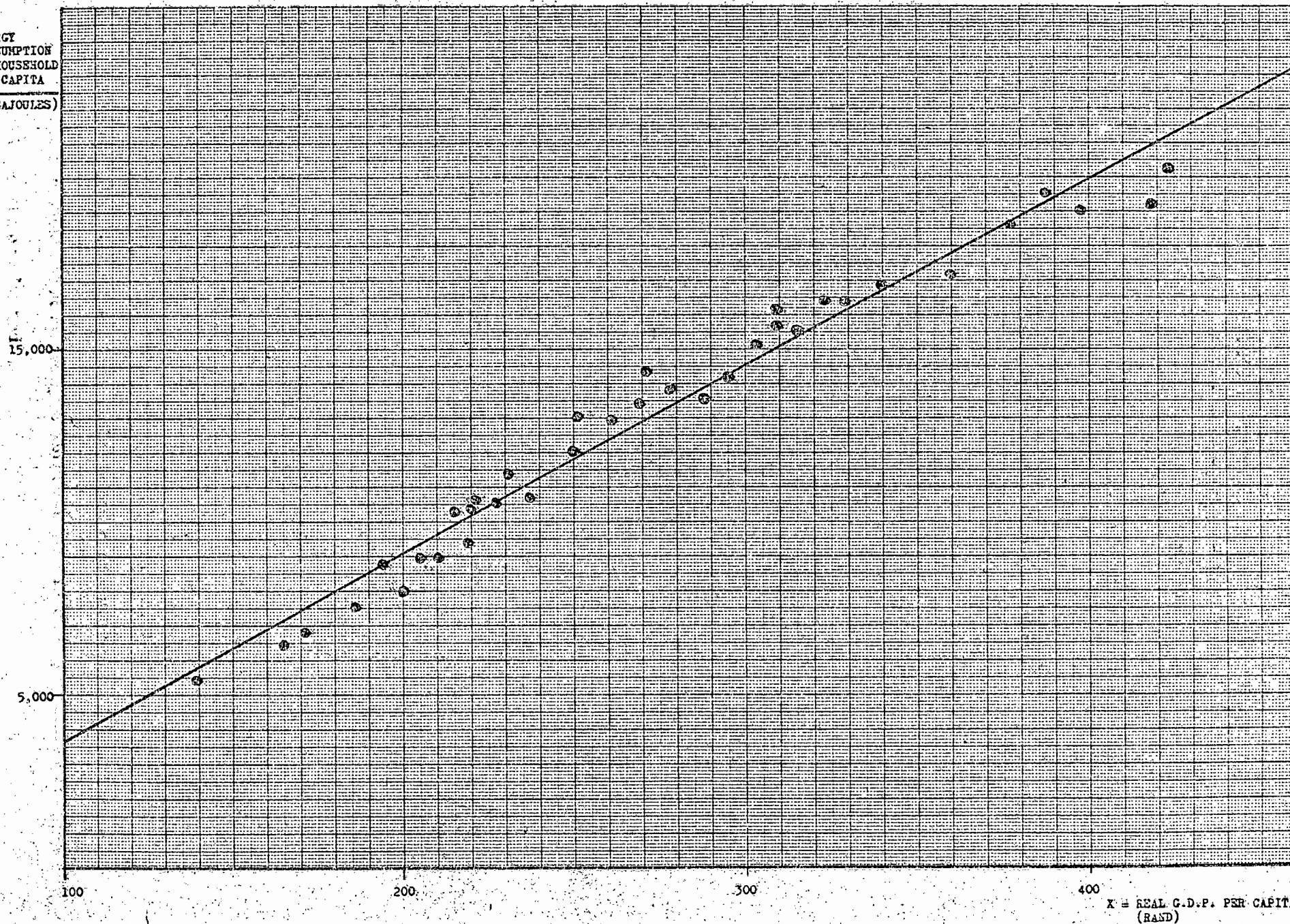
5,000

X = REAL PRIVATE CONSUMPTION
EXPENDITURE (R MILLION)

FIGURE 3: PER CAPITA ENERGY IN HOUSEHOLDS VERSUS PER CAPITA REAL GROSS DOMESTIC PRODUCT, 1933 - 1968

$$\hat{Y} = -1752.21 + 54.2493X$$

Y = ENERGY
CONSUMPTION
IN HOUSEHOLD
PER CAPITA
(MEGAJOULES)



According to calculations made by the Department of Planning in the five-yearly Economic Development Programme of the country, an average annual growth of 5.15 per cent in real private consumption expenditure is associated with a 5.5 per cent growth in real GDP.¹⁰⁷ If it is assumed that growth of this magnitude in real private consumption expenditure will continue to prevail over the entire forecast period, a forecast of energy demand in the households sector is made, as tabulated in Table 47. The 95 per cent confidence intervals¹⁰⁸ are also provided in respect of each of the forecast years, as shown.

TABLE 47: FORECAST OF ENERGY CONSUMPTION IN THE HOUSEHOLDS
SECTOR, 1968 - 2000

YEAR	REAL PRIVATE CONSUMPTION EXPENDITURE (1958 PRICES) (R MILLION) (1)	HOUSEHOLDS ENERGY CONSUMPTION (10 ⁶ MEGAJOULES) (2)
1968	5118	53516
1980	9404	102983 ± 3690
1990	15612	169639 ± 3857
2000	25918	280301 ± 4375

In accordance with overseas practice, especially in Europe,²⁰⁷ it was also investigated whether temperature contributes significantly towards variation in the energy consumption variables for different sectors, including the households sector. It was found throughout that temperature is not a significant variable in South Africa. The main reason for this is probably the fact that climatic conditions prevailing in different parts of this country are most heterogeneous and certainly not as uniform as experienced in Europe.

5.3.1.2 Industrial sector

The explanatory variables which were considered appropriate as leading indicators for energy consumed in the industrial sector included:

- population
- gross domestic product
- per capita gross domestic product
- industrial sector of the gross domestic product
- manufacturing production
- capital formation
- relative prices, and
- temperature

Of these it was found that the best explanatory variables are real gross domestic product and real value of gross manufacturing output as shown in Fig. 4 and Fig. 5, respectively.

Current values of gross manufacturing production were extracted from the Jubilee Issue of Statistics⁴²⁷ and further updated with statistics supplied in the latest Statistical Yearbooks.⁷¹⁷ (Column (4), Table 46). The series thus obtained were then adjusted for changes in prices using the consumer price index (October 1958 = 100) as shown in column (5) of Table 46. If prices for 1958 as a whole are taken as 100, the resulting real series on gross value of manufacturing output are obtained, as provided in column (6) of Table 46. Statistics on the consumer price index were obtained from the same sources as manufacturing output.

Linear models were again fitted to the two sets of observations. Industrial energy consumption is of course indicated by column (8) of Table 37. In the case where the real gross domestic product is used as determining variable, the calculated correlation coefficient equals 0.99, which is naturally again highly significant, with resulting equation:

FIGURE 4: INDUSTRIAL ENERGY VERSUS REAL GROSS DOMESTIC PRODUCT, 1933 - 1968

$$\hat{Y} = -35855.1 + 33.5822X$$

Y = ENERGY
CONSUMPTION
IN INDUSTRY
(10⁶ MEGAJOULES)

180,000

100,000

20,000

1,000

3,000

5,000

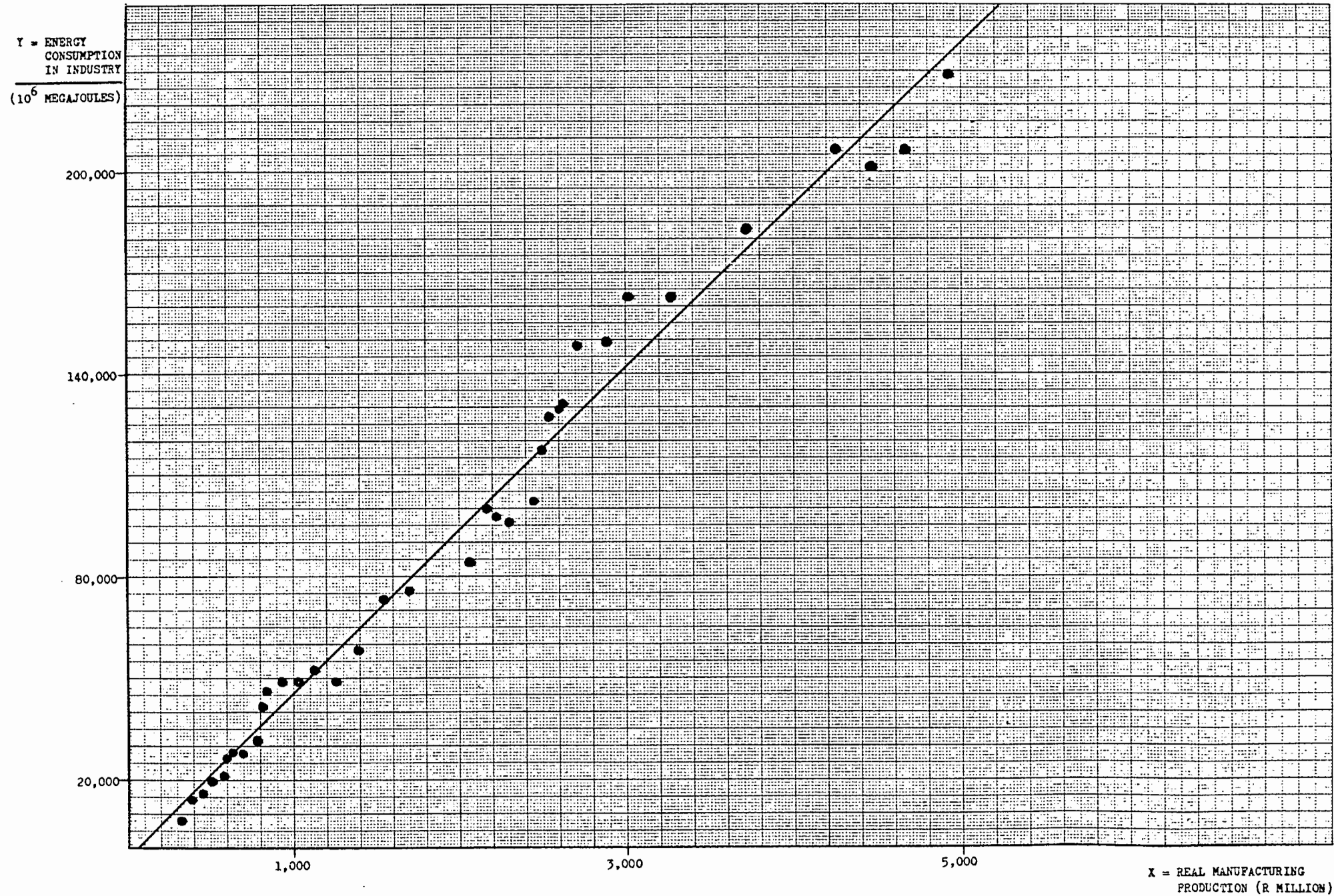
7,000

9,000

X = REAL G.D.P.
(B. MILLION)

FIGURE 5: INDUSTRIAL ENERGY VERSUS REAL VALUE OF GROSS MANUFACTURING OUTPUT, 1933 - 1968

$$\sqrt{Y} = -2943.1 + 48.2951\sqrt{X}$$



$$Y = -35855.1 + 33.5822X$$

where Y = industrial energy consumption
 X = real gross domestic product

Using real manufacturing output as independent variable, a correlation coefficient of 0.99 is found, with resultant equation:

$$Y = -2943.1 + 48.2951X$$

where Y = industrial energy consumption
 X = real manufacturing output

To discover which independent variable contributed the greater proportion of variation in the dependent variable, a step-wise regression analysis¹⁰⁹ was performed.

The conclusions drawn from this analysis were that both independent variables contribute almost equally, and it would therefore be possible to relate industrial energy consumption to either one or both, with the expectation of an equally good relationship.

In this instance, it was decided to include both variables in a multiple regression model. The reason for this decision was that it was felt that, in addition to manufacturing output, account should also be taken of overall economic growth, which may not necessarily be generated by the industrial sector alone. It may, however, be argued that the production of the industrial sector is equally a component of the gross domestic product, on the income side. This is so, but the indicator used, namely gross value of manufacturing output, is a more comprehensive measurement of output than the contribution of the industrial sector to the gross domestic product, in that it includes the value added by all factors of production. Gross

value of manufacturing output is also logically considered a better yardstick for the measurement of energy inputs into the production process.

The multiple regression model thus took the form:

$$Y = -23247.4 + 20.3357X_1 + 19.2399X_2$$

where Y = industrial energy consumption
 X_1 = real gross domestic product
 X_2 = real manufacturing output

The relationship yielded a multiple correlation coefficient of 0.99.

In forecasting industrial energy demand, use has been made of historical statistics on the sectoral composition of the real gross domestic product, as established by Du Piesanie.¹⁰³⁷ Statistics from this source were only available up to 1965 and were further brought up to date by using the Reserve Bank Bulletin. Figures appearing in the latter source are expressed in current prices and have been converted to real terms. The results are tabulated in Table 48. The fact that aggregate values of real GDP, prior to 1966, as shown in Table 48, differ slightly from the statistics provided in the first column of Table 46, does not need to give rise to concern as only the sectoral percentage contributions, provided in Table 48, will be used.

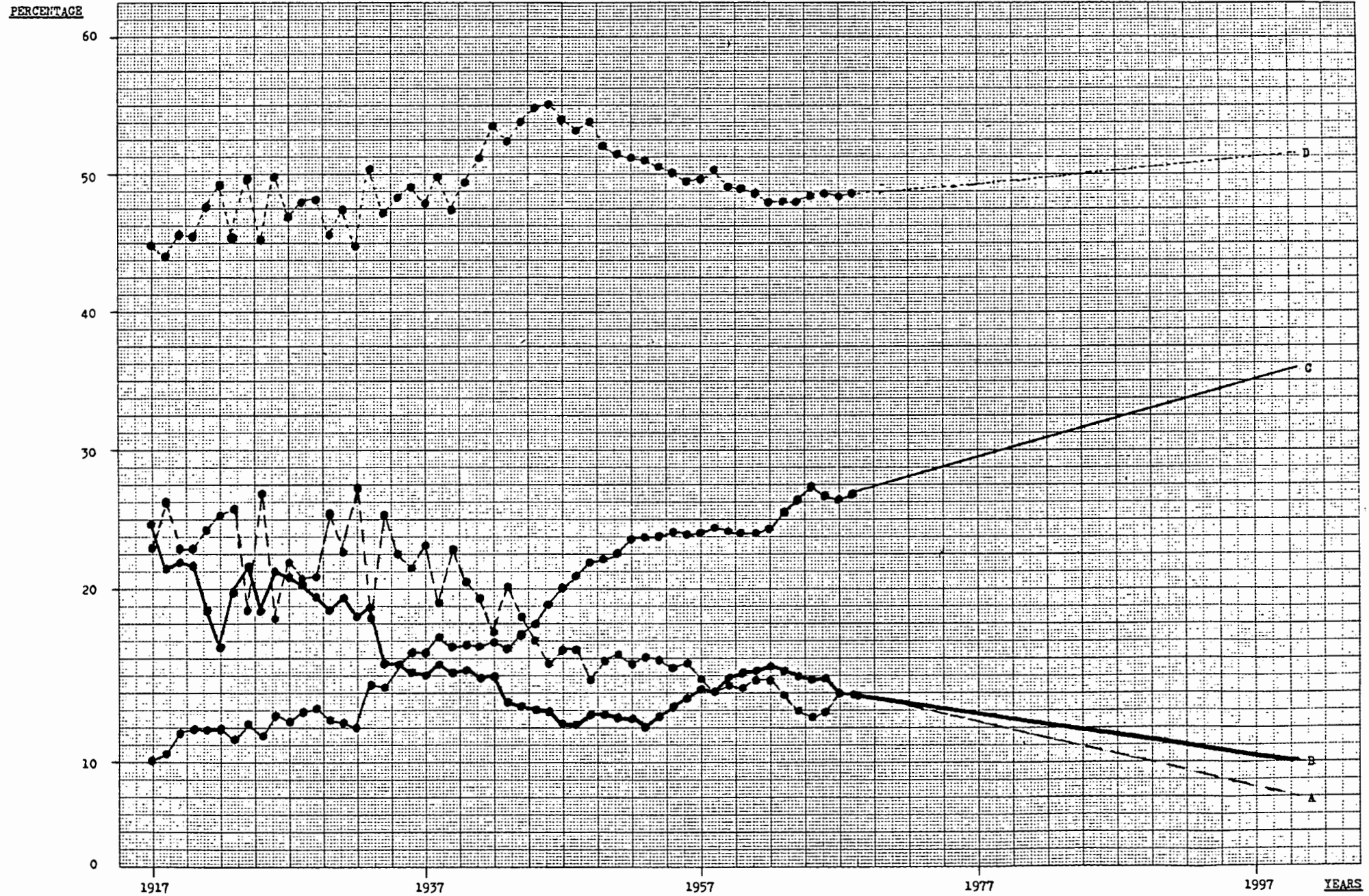
The historical percentage contributions of each kind of economic activity, thus established, are depicted in Fig. 6. No ultra long-range estimates of these sectoral contributions are available. They have therefore been extrapolated into the future, rather arbitrarily, at the same time exercising a certain degree of judgment. The resultant estimates of future contributions to the real GDP must therefore

TABLE 48: GROSS DOMESTIC PRODUCT BY KIND OF ECONOMIC ACTIVITY, 1917 - 1968

(1958 PRICES - R MILLION)

YEAR	AGRICULTURE FORESTRY AND FISHING	PERCENTAGE	MINING AND QUARRYING	PERCENTAGE	INDUSTRY	PERCENTAGE	SERVICES	PERCENTAGE	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1917	199.0	22.9	214.6	24.7	65.7	7.6	389.1	44.8	868.4
1918	239.2	26.3	195.5	21.5	74.6	8.2	401.0	44.1	910.3
1919	200.2	22.8	193.4	22.0	84.2	9.6	400.8	45.6	878.6
1920	199.7	22.8	189.6	21.6	87.1	9.9	400.0	45.6	876.4
1921	216.4	24.2	165.6	18.5	87.5	9.8	426.2	47.6	895.7
1922	229.5	25.3	142.2	15.7	89.4	9.9	445.7	49.2	906.8
1923	266.8	25.7	204.8	19.7	95.5	9.2	472.1	45.4	1039.2
1924	182.5	18.4	215.7	21.7	102.0	10.3	492.9	49.6	993.1
1925	315.9	26.9	216.8	18.4	111.7	9.5	531.4	45.2	1175.8
1926	196.8	17.9	234.2	21.3	120.2	10.9	547.5	49.8	1098.7
1927	269.8	21.9	256.0	20.8	129.1	10.5	575.8	46.8	1230.7
1928	260.9	20.7	256.0	20.4	139.5	11.1	601.5	47.8	1258.5
1929	270.1	20.9	251.1	19.4	147.8	11.4	623.6	48.2	1292.6
1930	344.4	25.4	250.6	18.5	143.7	10.6	619.4	45.6	1358.1
1931	277.4	22.7	236.9	19.4	127.2	10.4	580.1	47.5	1221.6
1932	345.8	27.2	229.3	18.0	127.6	10.0	568.4	44.7	1271.1
1933	208.1	17.9	217.9	18.7	152.0	13.1	586.7	50.4	1164.7
1934	366.1	25.3	210.8	14.6	186.2	12.9	680.8	47.2	1443.8
1935	341.1	22.5	222.2	14.6	221.7	14.6	734.0	48.3	1519.0
1939	360.9	21.5	235.9	14.0	258.8	15.4	824.0	49.1	1679.6
1937	427.9	23.1	256.0	13.8	283.0	15.3	888.5	47.9	1855.4
1938	345.0	19.0	264.7	14.6	301.3	16.6	905.1	49.8	1816.1
1939	452.9	22.9	275.1	13.9	314.4	15.9	939.0	47.4	1981.4
1940	419.9	20.4	291.4	14.2	328.2	16.0	1016.0	49.4	2055.5
1941	422.1	19.3	296.9	13.6	347.0	15.9	1118.0	51.2	2184.0
1942	362.7	16.8	296.3	13.7	348.0	16.1	1156.3	53.5	2163.3
1943	459.1	20.1	269.6	11.8	357.0	15.7	1195.1	52.4	2280.8
1944	412.9	17.9	266.9	11.6	385.6	16.7	1241.3	53.8	2306.7
1945	389.3	16.3	270.2	11.3	416.3	17.5	1307.9	54.9	2383.7
1946	354.8	14.6	270.2	11.2	457.9	18.9	1340.2	55.3	2423.1
1947	397.6	15.7	261.5	10.3	508.9	20.1	1369.1	54.0	2537.1
1948	429.0	15.7	282.2	10.3	572.2	20.9	1457.6	53.2	2741.0
1948	377.6	13.5	306.1	10.9	613.4	21.9	1510.0	53.8	2807.1
1950	438.8	14.8	323.0	10.9	660.1	22.2	1546.6	52.1	2968.5
1951	476.2	15.3	332.3	10.7	704.3	22.6	1606.8	51.5	3119.6
1952	471.3	14.6	344.3	10.7	760.5	23.6	1652.1	51.2	3228.2
1953	514.1	15.1	342.6	10.1	803.9	23.7	1737.7	51.1	3398.3
1954	536.3	14.8	390.5	10.8	859.9	23.8	1830.0	50.6	3616.7
1955	544.4	14.3	437.9	11.5	917.1	24.1	1907.2	50.1	3806.6
1956	587.2	14.6	483.7	12.1	955.0	23.8	1985.6	49.5	4011.5
1957	563.4	13.5	536.0	12.8	1008.1	24.1	2080.6	49.7	4188.1
1958	541.7	12.6	544.7	12.7	1050.6	24.4	2160.9	50.3	4297.9
1959	589.9	13.1	610.1	13.6	1087.9	24.2	2209.1	49.1	4497.0
1960	601.8	12.8	657.5	14.0	1131.1	24.1	2297.1	49.0	4687.5
1961	661.9	13.4	697.2	14.1	1190.5	24.0	2407.1	48.6	4956.7
1962	698.5	13.4	749.5	14.4	1265.9	24.3	2504.0	48.0	5217.9
1963	685.4	12.3	787.6	14.1	1427.9	25.6	2684.2	48.1	5585.1
1964	685.9	11.2	837.7	13.7	1639.7	26.9	2936.2	48.1	6099.5
1965	693.9	10.8	867.2	13.5	1761.7	27.3	3121.4	48.4	6444.2
1966	805.5	11.1	987.0	13.6	1937.6	26.7	3526.9	48.6	7257.0
1967	979.6	12.5	987.5	12.6	2076.8	26.5	3793.1	48.4	7837.0
1968	998.0	12.3	998.0	12.3	2174.6	26.8	3943.4	48.6	8114.0

FIGURE 6: PERCENTAGE CONTRIBUTIONS OF AGRICULTURE FORESTRY AND FISHING, (A), MINING AND QUARRYING, (B), INDUSTRY, (C), AND SERVICES, (D), TO REAL GROSS DOMESTIC PRODUCT, 1917 - 2000.



not be seen as economic forecasts, but rather as a series of reasoned assumptions. The results, so obtained, do however correspond fairly well to views promulgated by authoritative speakers in recent times.

By applying the percentages, thus obtained, against future estimates of GDP, (assumed to grow at $5\frac{1}{2}$ per cent), quantitative estimates are obtained of the future values of each kind of economic activity, as shown in Table 49.

TABLE 49: FORECAST OF GROSS DOMESTIC PRODUCT BY KIND OF
ECONOMIC ACTIVITY, 1968 - 2000
(1958 PRICES - R MILLIONS)

YEAR	AGRICULTURE ETC.	%	MINING ETC.	%	INDUSTRY	%	SERVICES	%	TOTAL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1968	998	12.3	998	12.3	2175	26.8	3943	48.6	8114
1980	1496	9.7	1620	10.5	4674	30.3	7636	49.5	15427
1990	1897	7.2	2398	9.1	8722	33.1	13334	50.6	26351
2000	2251	5.0	3466	7.7	16159	35.9	23136	51.4	45011

From Table 49 it is evident that the contribution of the primary sectors of the economy will continue to decline, with consequent further increases in the relative contributions of the secondary and tertiary sectors. This is quite realistic - it is the outflow of a maturing economy, and is in accordance with experience in other parts of the world. It is also noted that average annual growth in the absolute contribution of the industrial sector, column (5), is 6.6 per cent between 1968 and 1980, 6.5 per cent 1980 to 1990 and 6.4 per cent between 1990 and 2000. It was finally

assumed that real manufacturing output will also increase at these rates for these periods.

It is now possible to derive a forecast of industrial energy consumption, utilizing future estimates of the two explanatory variables, as shown in Table 50. The 95 per cent confidence limits of the forecasts are again indicated, as shown in the table.

TABLE 50: FORECAST OF ENERGY CONSUMPTION IN THE INDUSTRIAL
SECTOR, 1968 TO 2000

YEAR	REAL GROSS DOMESTIC PRODUCT (1958 PRICES - R MILLION)	REAL VALUE OF GROSS MANUFACTURING PRODUCTION (1958 PRICES - R MILLION)	INDUSTRIAL ENERGY CONSUMPTION (10 ⁶ MEGAJOULES)
	(1)	(2)	(3)
1968	8114	4914	229167
1980	15427	10563	493770 ± 24785
1990	26351	19709	915181 ± 35608
2000	45011	36512	1594767 ± 58885

Relationships between industrial energy consumption and various other variables, including temperature and gross and net capital formation, were also examined. It was again established that temperature does not contribute significantly towards variation in the dependent variable. In the case of the two variants of capital formation, it was found that no significant correlation exists. This was caused by the fact that, whereas industrial energy demand was growing steadily, capital formation (gross and net) formed very erratic series.

5.3.1.3 Mining sector

It is clear that the only variables which can meaningfully be considered to explain variation in the demand for energy by the mining sector are indices expressing mining activity, such as value or volume of mining production. Table 46 columns (7) and (8) provide historical economic series on value and volume of mining production, respectively. Column (7) was obtained from *Odu Piesanie*^{103/} and is the historical contribution of mining and quarrying to the real gross domestic product. As already mentioned in Section 5.3.1.2, statistics from this source are only available up to 1965 and they have been augmented by series provided in the Reserve Bank Quarterly Bulletin. As statistics taken from the latter source are in current terms, they have been deflated by the metals wholesale price index, for the years 1966 to 1968.

Historical statistics on the volume of mining production, (column (8), Table 46), up to 1964, were obtained from a publication of the Transport Research Centre^{110/} and further brought up to date using the latest Statistical Yearbooks^{71/}.

Useful energy consumption in the mining sector (column (8), Table 38) was then correlated with the two economic series on value and volume of mining production. The scatter diagrams are provided in Figures 7 and 8, respectively.

In the case of real value of mining production, a correlation coefficient of 0.82 is obtained with corresponding equation:

$$Y = 28829.2882927 + 21.6995X$$

where Y = energy consumption in the mining sector
X = real value of mining production

$$\hat{Y} = 28829.7 + 21.6995X$$

FIGURE 7. MINING ENERGY VERSUS REAL VALUE OF MINING PRODUCTION, 1933 - 1968

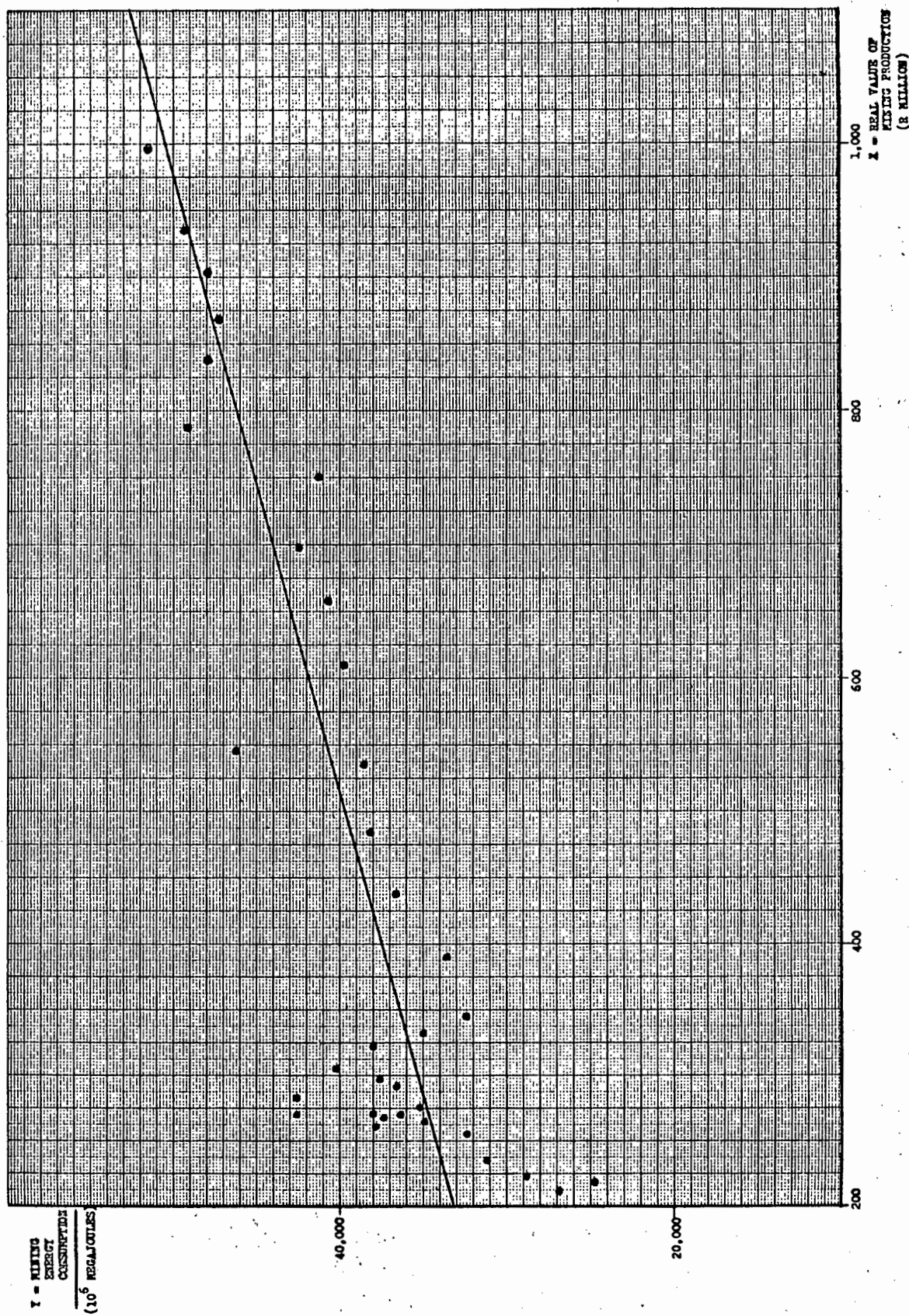
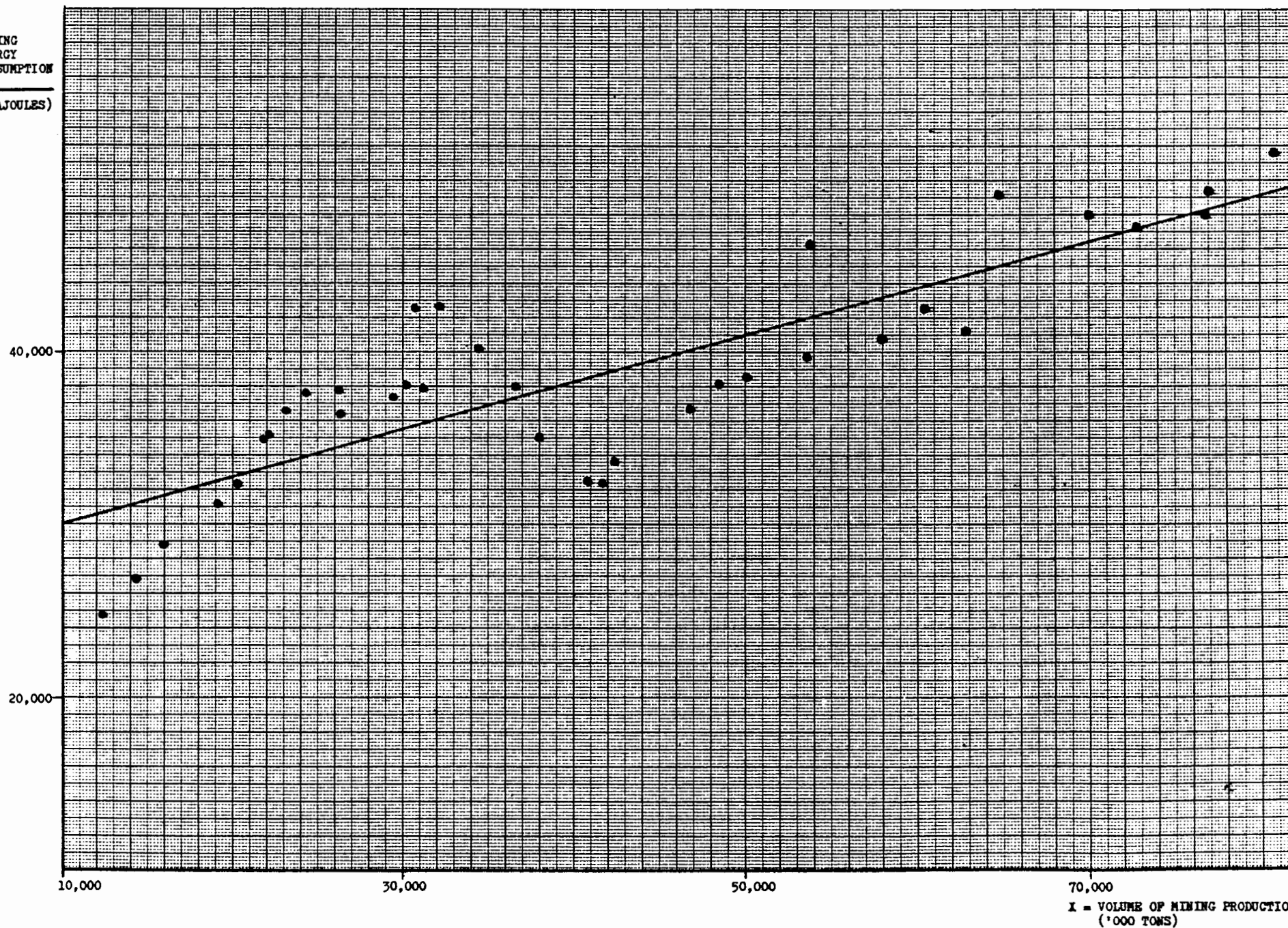


FIGURE 8: MINING ENERGY VERSUS VOLUME OF MINING PRODUCTION, 1933 - 1968

$$\bar{Y} = 27309.5 + 0.27380X$$

Y = MINING
ENERGY
CONSUMPTION
(10⁶ MEGAJOULES)



Using volume of mining production as economic indicator, the calculated correlation coefficient is 0.84 with equation:

$$Y = 27309.5 + 0.27380X$$

where Y = energy consumption in the mining sector

X = volume of mining production

It was however observed, in the case of both scatter diagrams, that observations from 1933 to 1951 showed extremely erratic tendencies. This appeared to be the result of erratic variations in energy consumed during this period. Further investigations showed that this was caused by available figures on the consumption of coal in this sector. As there is a certain degree of doubt regarding the accuracy of the earlier statistics on coal consumption in this sector, it was decided to omit the observations from 1933 to 1951 from the regression. Since a similar behaviour is noted in the observations for the years 1958 and 1963, it was decided to omit these also.

The new, adjusted scatter diagrams are constructed in Figures 9 and 10. The regressions were also calculated afresh.

The adjusted relationship between energy and value of mining production yields a correlation coefficient of 0.99 with equation:

$$Y = 23276.4 + 27.7669X$$

where Y = energy consumption in the mining sector

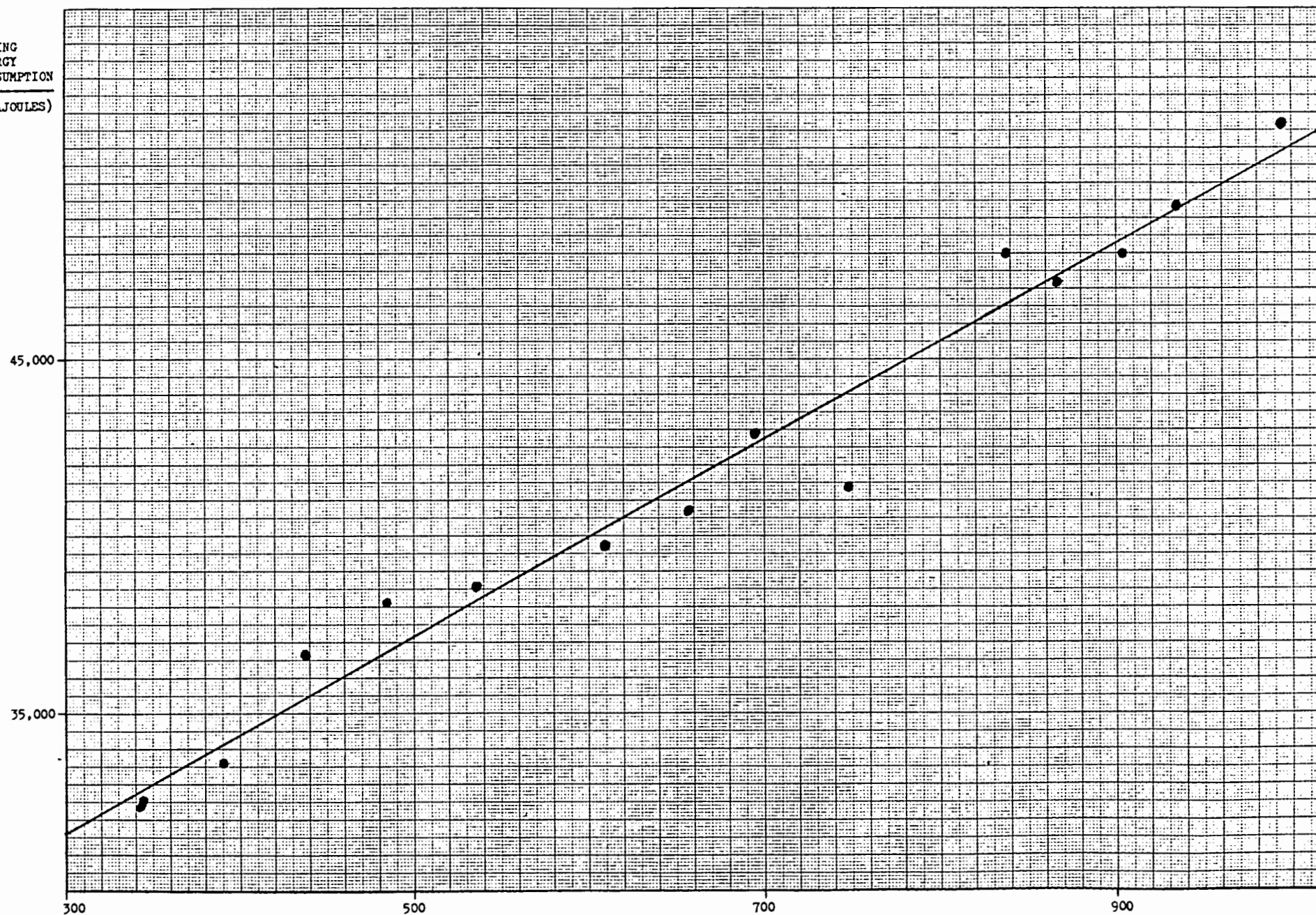
X = real value of mining production

The adjusted relationship between energy and volume of mining production has a coefficient of correlation of 0.99 with calculated regression line:

FIGURE 9: ADJUSTED RELATIONSHIP OF MINING ENERGY AND REAL VALUE OF MINING PRODUCTION, 1952 - 1968

$$\hat{Y} = 23276.4 + 27.7669X$$

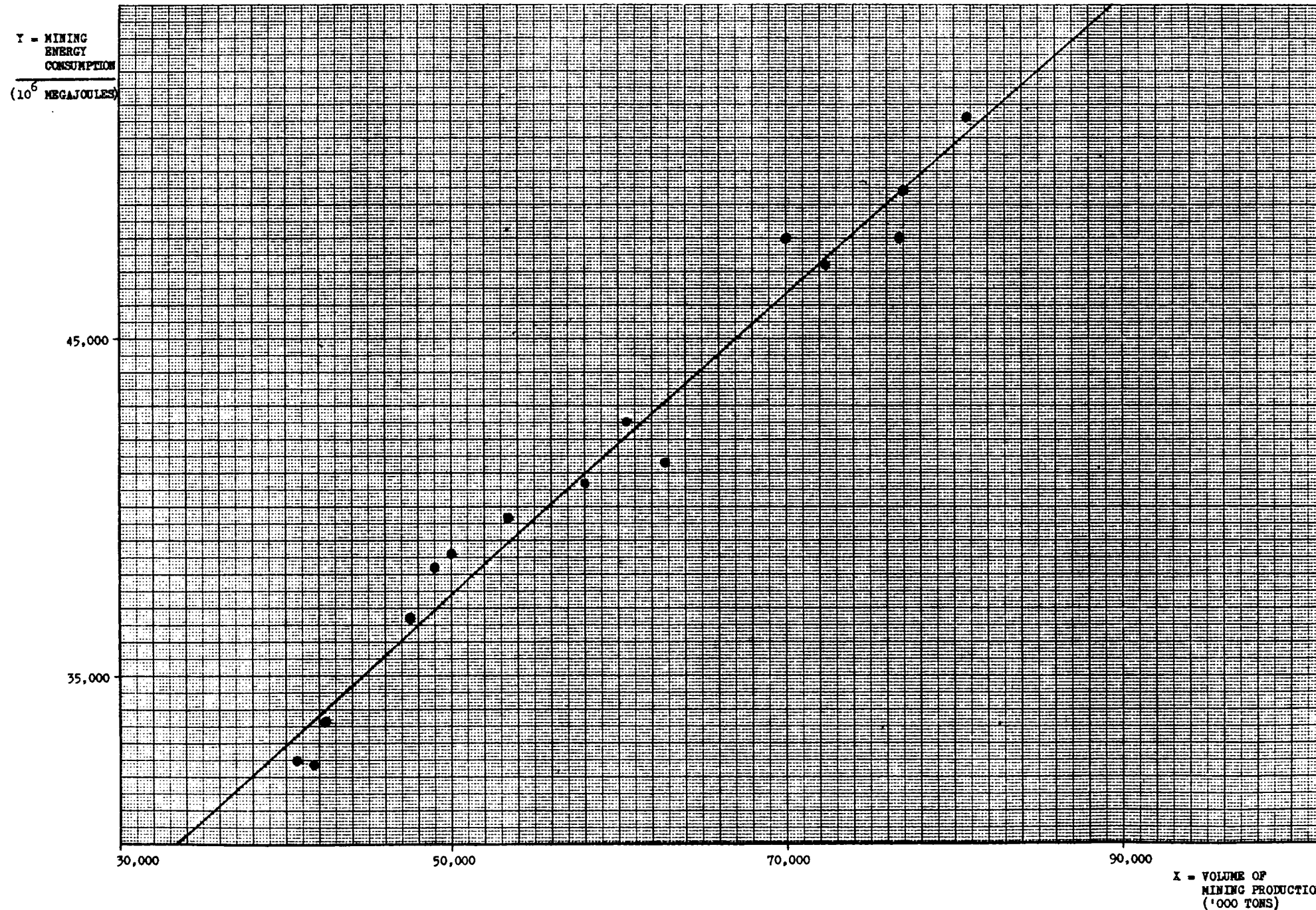
Y = MINING
ENERGY
CONSUMPTION
(10⁶ MEGAJOULES)



X = REAL VALUE OF
MINING PRODUCTION
(R MILLION)

FIGURE 10: ADJUSTED RELATIONSHIP OF MINING ENERGY AND VOLUME OF MINING PRODUCTION, 1952 - 1968

$$\bar{Y} = 15109.5 + 0.44677X$$



$$Y = 15109.5 + 0.44677X$$

where Y = energy consumption in the mining sector

X = volume of mining production

From the above, it is evident that either of the two economic series, i.e. value of volume of mining production, is suitable for use as determining variable. As the selection of volume of production would raise problems regarding its forecasting, inasmuch as a forecast would then have to be made of individual types of mining, it was decided to use mining's contribution to the real GDP.

By using future estimates of mining's contribution to real GDP, as given in column (3) of Table 49, a forecast of energy consumption in this sector is derived, as summarised in Table 51.

TABLE 51: FORECAST OF ENERGY CONSUMPTION IN THE MINING
SECTOR, 1968 TO 2000

YEAR	MINING'S CONTRIBUTION TO REAL GROSS DOMESTIC PRODUCT (1958 PRICES - R MILLION)	ENERGY CONSUMPTION IN THE MINING SECTOR (10 ⁶ MEGAJOULES)
	(1)	(2)
1968	998	51649
1980	1620	68258 ± 3701
1990	2398	89866 ± 5557
2000	3466	119522 ± 8396

The 95 per cent confidence intervals of the energy forecasts, for successive forward years, is again indicated in column (2) of Table 51.

5.3.1.4 Transport sector

The approach to the forecasting of energy demand in this sector has been to find indices considered representative of all possible modes of transport, including:

- road transport,
- rail transport,
- air transport, and
- marine transport.

In addition, it was also investigated to what extent overall transport requirements are affected by general economic growth.

It was eventually found that variation in the historical energy demands of this sector is very satisfactorily explained, individually, by the following three variables:

- gross domestic product,
- railway ton-miles, and
- total motor vehicle population.

As before, the real gross domestic product is supplied in the first column of Table 46. Historical railway ton-miles, up to the year 1959, were obtained from the Jubilee Issue of Statistics^{42/} and brought up to date with figures from the latest Statistical Yearbooks^{71/} and Quarterly Bulletins of Statistics.^{41/} The information is provided in the ninth column of Table 46. The series on motor vehicles are available in column (3) of Table 34 (page 191) and include motor cars and all commercial vehicles (excluding tractors and motor cycles).

If the energy demands of the transport sector (column (8), Table 39) are now correlated with each of the three economic magnitudes

discussed above, scatter diagrams are obtained, as provided in Figures 11, 12 and 13.

The regression analysis carried out, using real GDP as economic indicator, yielded a correlation coefficient of 0.9965 with equation:

$$Y = -2504.9 + 6.9879X$$

where Y = energy consumption in the transport sector

X = real gross domestic product

Using railway ton-miles as determining variable, a coefficient of correlation of 0.9960 is obtained with the following straight line:

$$Y = -2493.7 + 1.5090X$$

where Y = energy consumption in the transport sector

X = railway ton-miles

Lastly, the calculated regression of transport energy consumption versus total motor vehicle population has a correlation coefficient of 0.9906 with equation:

$$Y = 3639.8 + 0.0297X$$

where Y = energy consumption in the transport sector

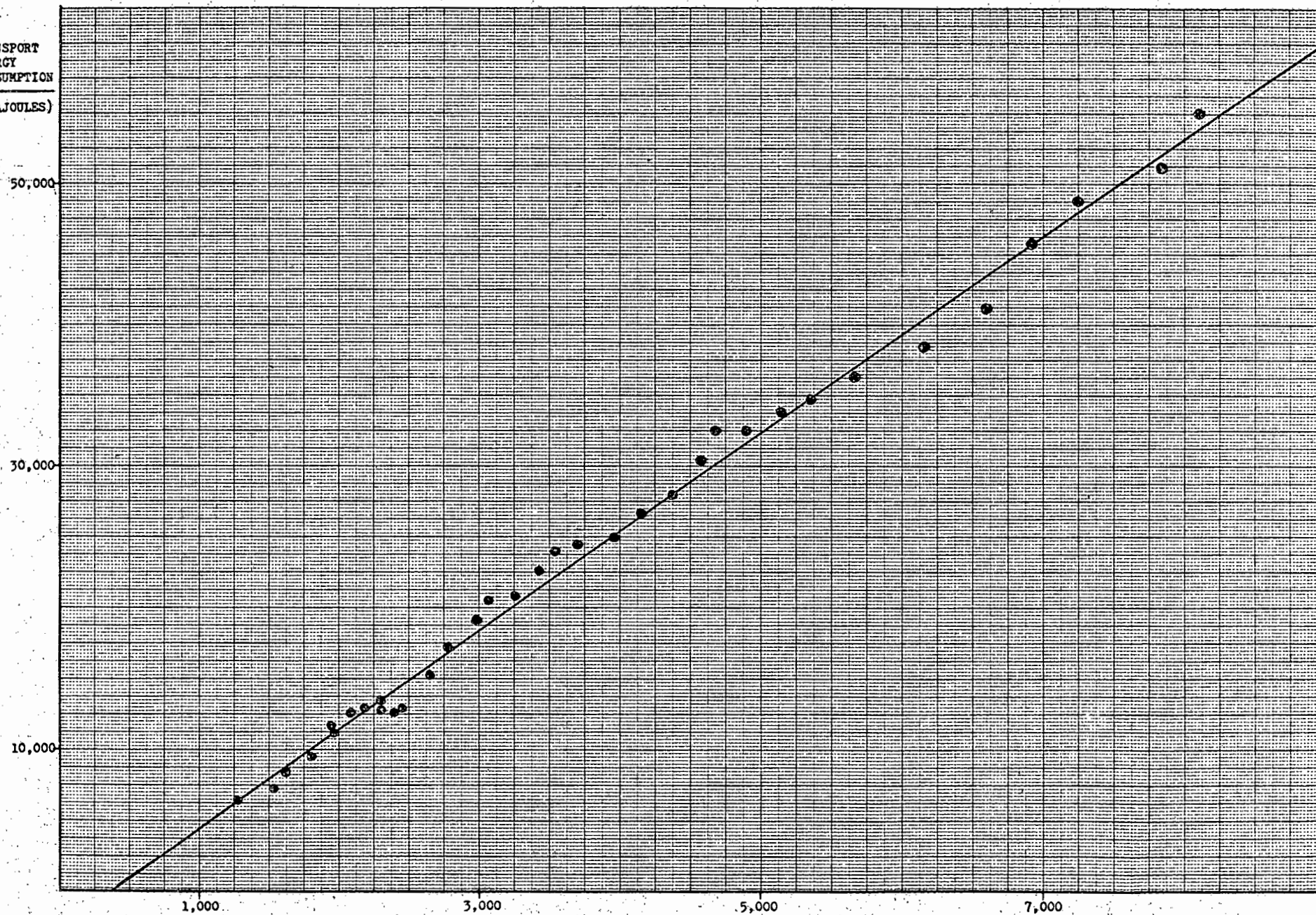
X = total motor vehicle population

It is, therefore, clear that any one of the three explanatory variables discussed could successfully be employed to forecast the demand for energy in this sector. Forecasts have in fact been made on all three and the results, as could be expected, were virtually identical. As in the case of the industrial sector, a step-wise regression was also carried out to establish which variable contributed most to the variation in the dependent variable. Needless to say, it was found that they all contributed equally. Normally, on statistical

FIGURE 11: TRANSPORT ENERGY VERSUS REAL GROSS DOMESTIC PRODUCT, 1933 - 1968

$$\hat{Y} = -2504.9 + 6.9879X$$

Y = TRANSPORT
ENERGY
CONSUMPTION
(10⁶ MEGAJOULES)



X = REAL G.D.P.
(R MILLION)

FIGURE 12: TRANSPORT ENERGY VERSUS RAILWAY TON-MILES, 1933 - 1968

$$\bar{Y} = -2493.7 + 1.5090\bar{X}$$

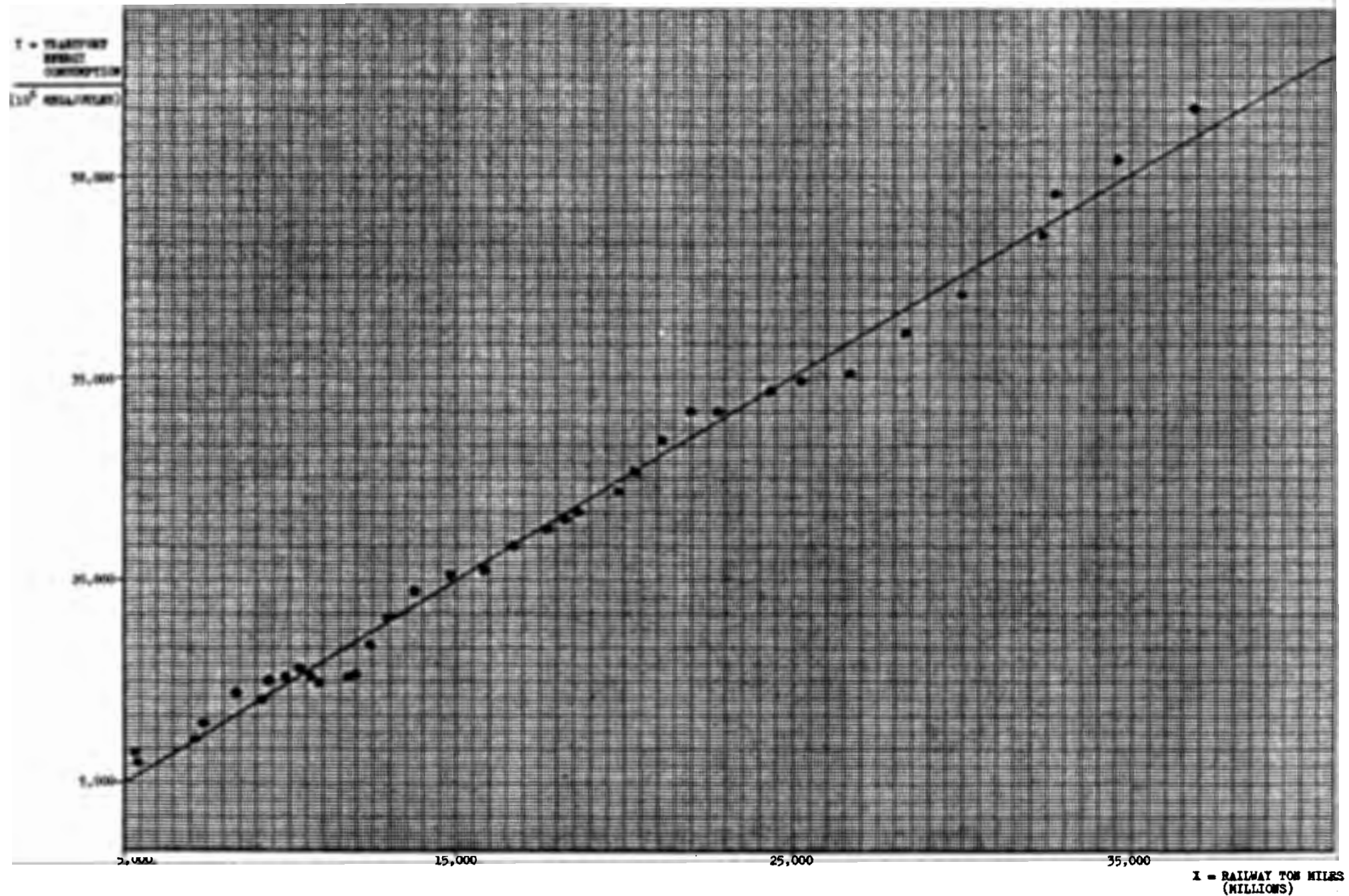
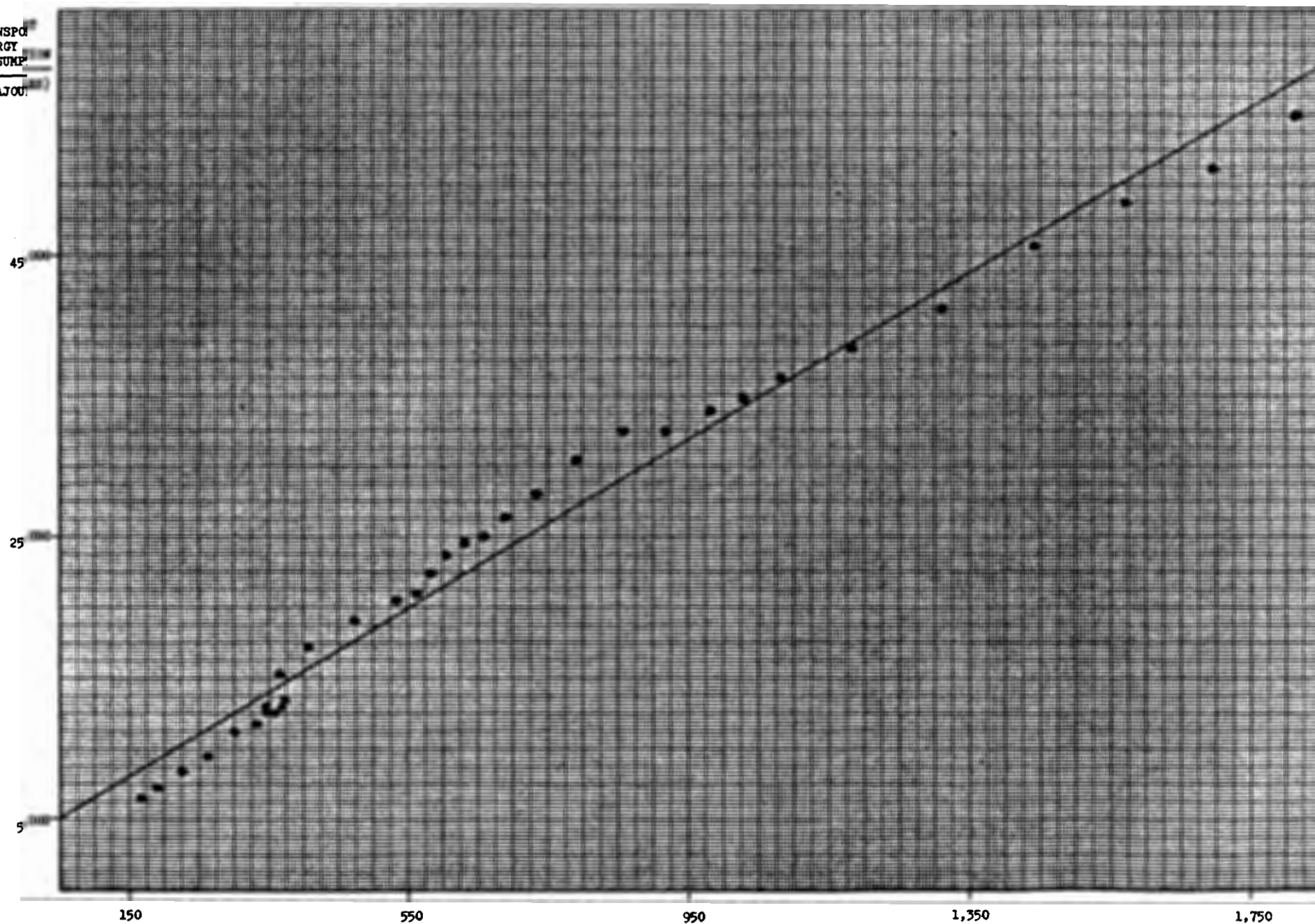


FIGURE 13: TRANSPORT ENERGY VERSUS MOTOR VEHICLE POPULATION, 1953 - 1968

$$\hat{Y} = 3639.8 + 0.0297X$$

Y = TRANSPORT
ENERGY
CONSUMPTION
(10⁶ MEGAJOULES)



X = MOTOR VEHICLE POPULATION
(000's)

grounds, one would select the alternative yielding the highest degree of correlation and the lowest standard deviation. On economic grounds, however, it would logically be more correct, in addition to general economic growth, also to take account of railway ton-miles and the motor vehicle population; the two variables which quantify the development in the two most important categories of this sector, namely rail transport and road transport. It appears reasonable to contend that the energy demands of the transport sector are logically more intimately related to developments in the road and rail sub-sectors. The point is, however, taken that the latter two variables are very closely related to general economic growth.

It was therefore decided to combine all three explanatory variables in a multiple regression model as follows:

$$Y = -704.3 + 0.01451X_1 + 1.03299X_2 + 0.00950X_3$$

where Y = energy consumption in the transport sector

X_1 = real gross domestic product

X_2 = railway ton-miles

X_3 = total motor vehicle population,

with $R^2 = 99.7$

If forecasts of the three independent variables can be made, a forecast can be made of energy consumed in the transport sector. A forecast of the real GDP is available in Table 49, column (9). Railway ton-miles were extrapolated using average growth rates obtained in forecasts already available.¹¹⁰

The total motor vehicle population was correlated with real private consumption expenditure (column (1), Table 47) as shown in Fig. 14. A correlation coefficient of 0.9962 is obtained with resulting equation:

FIGURE 14: MOTOR VEHICLE POPULATION VERSUS REAL PRIVATE CONSUMPTION EXPENDITURE, 1946 - 1968

$\bar{Y} = -584309 + 467.46655X$

Y = MOTOR
VEHICLE
POPULATION

2,000,000

1,000,000

0

2,000

3,000

4,000

5,000

X = REAL PRIVATE CONSUMPTION EXPENDITURE
(R MILLION)

$$Y = -584309.1 + 467.4666X$$

where Y = total motor vehicle population

X = real private consumption expenditure

In this way, the following forecast of the motor vehicle population is obtained:-

TABLE 52: FORECAST OF THE TOTAL MOTOR VEHICLE POPULATION, 1968 TO 2000

YEAR	REAL PRIVATE CONSUMPTION EXPENDITURE (1958 PRICES) (R MILLION)	TOTAL MOTOR VEHICLE POPULATION ('000)
	(1)	(2)
1968	5118	1817
1980	9404	3812 $\pm$ 29
1990	15612	6714 $\pm$ 50
2000	25918	11532 $\pm$ 88

The 95 per cent confidence intervals are again indicated.

By using forecasts of the three independent variables, so established, it now becomes possible to derive a forecast of energy demands in the transport sector, as outlined in Table 53. The 95 per cent confidence limits of the forecasts for each successive year were also calculated, as outlined in the table.

TABLE 53: FORECAST OF ENERGY CONSUMPTION IN THE TRANSPORT SECTOR

1968 - 2000

YEAR	REAL GROSS DOMESTIC PRODUCT 1958 PRICES (R MILLION)	RAILWAY TON-MILES (MILLIONS)	TOTAL MOTOR VEHICLE POPULATION ('000)	ENERGY CONSUMPTION IN THE TRANSPORT SECTOR (10 ⁶ MEGAJOULES)
	(1)	(2)	(3)	(4)
1968	8114	36958	1817	55122
1980	15427	64870	3812	104648 ± 4519
1990	26351	103670	6714	173910 ± 10479
2000	45011	165678	11532	286417 ± 22615

The effect on energy demands in the transport sector of variables quantifying the development of two further modes of transport, i.e. aviation and marine transport, was also examined. In the former category, trends in passenger miles flown, freight miles flown, and the aggregate of both, were considered. In the case of the latter, energy demands were correlated with total shipping cargo handled at South African ports as well as coastal shipping cargo handled. The relationships obtained by using these variables were, however, generally unsatisfactory. The reason for this is possibly that aviation and marine transport are relatively unimportant in relation to the total domestic transport needs of the country. These variables have consequently been excluded from the analysis and the resulting forecast.

5.3.1.5 Total all sectors

It is now possible to establish a forecast of total energy consumption, over all sectors, by adding the results obtained in Sections 5.3.1.1 to 5.3.1.4. These results are summarised in Table 54.

The sectoral relationships were tested for serial correlation using the Durbin-Watson d-test,¹⁰⁵⁷ as indicated in Table 54. As was to be expected from the high degree of correlation, there was evidence of slight serial correlation in all relationships.

If serial correlation is present in historical relationships it causes relatively inaccurate forecasts, inasmuch as it tends to widen the confidence intervals applicable to forecasts. As can be seen from the results tabulated in Table 54, the sizes of the confidence intervals obtained are so small that the question of the presence of serial correlation really becomes an academic consideration.

In spite of this, the magnitude of the effect on the forecasts of serial correlation was investigated. The relationship in the transport sector, which showed the highest degree of serial correlation, was corrected by transforming the variables. (See Johnston¹⁰⁵⁷ pp. 197 - 199). The transformed relationship produced forecasts almost identical to the original relationship, even in 2000 AD.

As a global control, total energy consumption (all sectors), as established in column (8) of Table 40, was correlated with a number of economic indicators. The best relationship was found by using the real gross domestic product as determining variable, as shown in Fig. 15. The calculated regression yielded a coefficient of correlation of 0.995

TABLE 54: A FORECAST OF TOTAL ENERGY CONSUMPTION IN SOUTH AFRICA, 1968 TO 2000

10⁶ MEGAJOULES

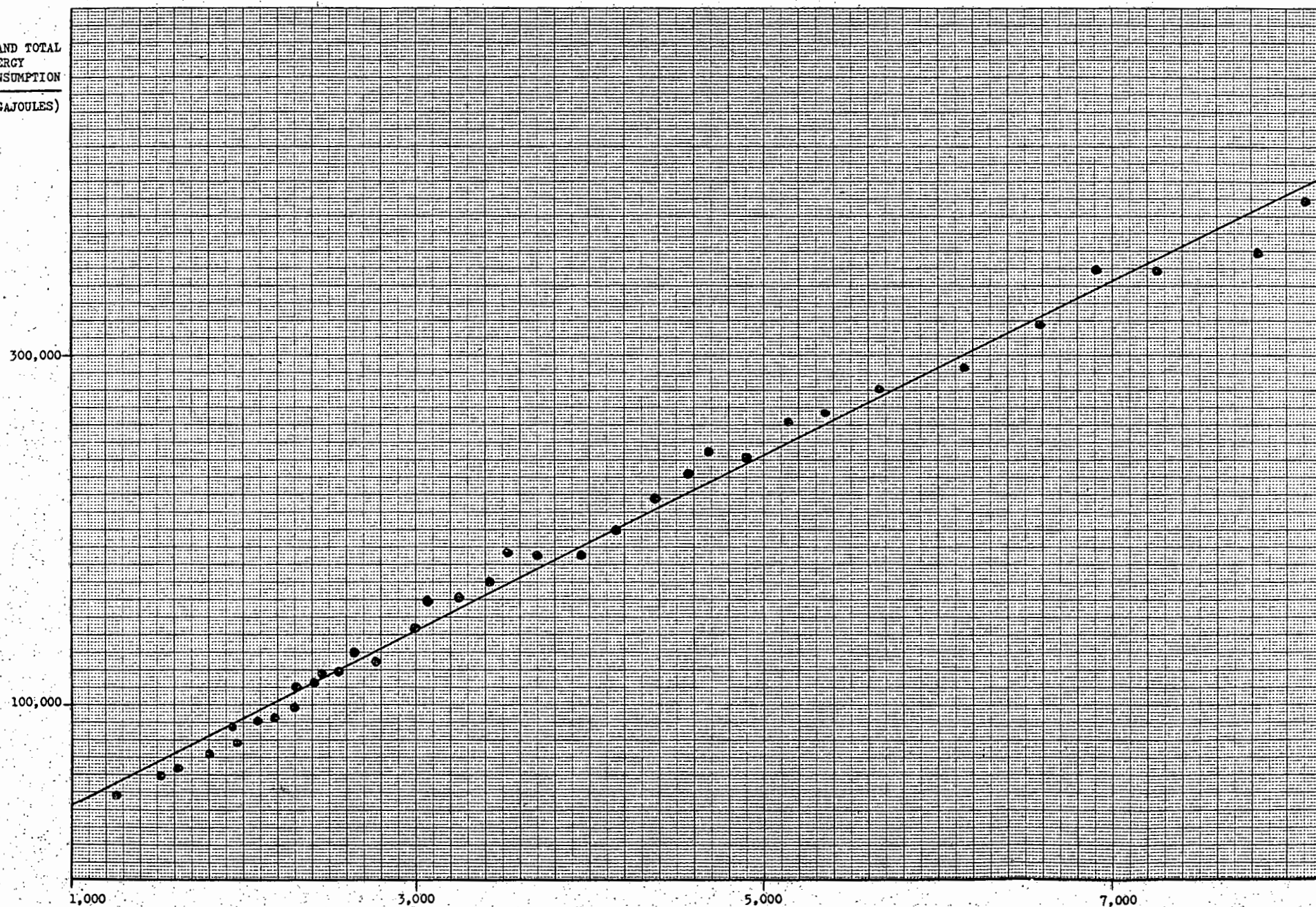
DEMAND SECTOR	ECONOMIC INDICATORS USED	EQUATION	P-VALUE	DURBIN-WATSON STATISTIC	CORRELATION COEFFICIENT	FORECAST			95 PER CENT CONFIDENCE INTERVALS		
						1980	1990	2000	1980	1990	2000
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. HOUSEHOLDS	- REAL PRIVATE CONSUMPTION EXPENDITURE	$Y = 2017.5 + 10.73675X$	689.507**	0.6085**	0.98511	102,983	169,639	280,301	± 3690	± 3857	± 4375
2. INDUSTRY	- REAL GROSS DOMESTIC PRODUCT (X ₁)	$Y = 23247.4 + 20.33571X_1 + 19.23985X_2$	1410.026**	1.032**	0.98519	493,770	915,181	1594,767	±24785	±35608	±58885
	- REAL MANUFACTURING PRODUCTION (X ₂)										
3. MINING	- REAL VALUE OF MINING PRODUCTION	$Y = 23276.4 + 27.76689X$	443.25**	2.150	0.98565	68,258	89,866	119,522	± 3701	± 5557	± 8396
4. TRANSPORT	- REAL GROSS DOMESTIC PRODUCT (X ₁)	$Y = -704.309 + 0.01451X_1 + 1.03299X_2 + 0.0095X_3$	2106.989**	0.5852**	0.99748	104,648	173,910	286,417	± 4519	±10479	±22615
	- RAILWAY TON-MILES (X ₂)										
	- TOTAL MOTOR VEHICLE POPULATION (X ₃)										
5. TOTAL ALL SECTORS (SECTORS 1 - 4)						769,659	1348,596	2281,007			
6. TOTAL ALL SECTORS (CONTROL FORECAST)	REAL GROSS DOMESTIC PRODUCT	$Y = -7828.9 + 50.17977X$	3500.975**		0.99518	766,298	1314,464	2250,823	±28,058	±43507	±73604

** DENOTES SIGNIFICANCE AT THE 1 PER CENT PROBABILITY LEVEL

FIGURE 15: TOTAL ENERGY CONSUMPTION VERSUS REAL GROSS DOMESTIC PRODUCT, 1933 - 1968

$$\bar{Y} = -7828.94 + 50.1798\bar{X}$$

Y = GRAND TOTAL
ENERGY
CONSUMPTION
(10⁶ MEGAJOULES)



X = REAL G.D.P. (R MILLION)

with equation:

$$Y = -7828.9 + 50.1798X$$

where Y = total energy consumption

X = real gross domestic product

The 95 per cent confidence interval was similarly constructed for this control forecast as indicated in Table 54.

From this table, it is evident that the forecast of total energy consumption, established by the addition of all sectors, is remarkably close to the results obtained by the control forecast.

It must, however, be observed that the narrowness of the confidence limits seem to suggest that considerable faith may be attached to the accuracy of the forecasts indicated, even those for the year 2000. This may be so statistically, but it has to be borne in mind that many factors, assumed to hold constant or to progress at a constant rate in the future, may deviate from their historical course. In this respect, technological innovation could naturally have a significant impact. The confidence limits indicated must, therefore, be interpreted with a certain degree of caution.

5.3.2 Market shares of forms of energy

Having obtained forecasts of the sectoral demands for energy, the next step is to establish the contribution of each energy-producing agent to the sectoral total. In this respect, trends in the market shares for different energy-producing agents, as outlined in Tables 41 to 45, will be analysed and projected.

Some research workers²⁰⁷ have adopted the strategy of linking the progression of these market shares to economic indicators and extrapolating market holdings on the basis of observed past relationships. The statistical validity of this, to say the least, is doubtful and lack of data renders this approach pointless in any case, especially in South Africa.

The approach followed in this study was to study historical trends in the contributions of individual energy-producing agents to the sector totals. In cases where historical patterns conformed to smooth, reliable trends, the historical relationships were extrapolated into the future, obviously exercising judgment, and not necessarily adhering too rigidly to the results of such extrapolations. The approach also has not always been followed slavishly; in some cases, where sound evidence suggested otherwise, other strategies were adopted, sometimes even departing from the historical trend.

Normally, as will be seen, shifts occurring in market contributions operate smoothly and slowly and are almost always easily explained. In Chapter 4 (Section 4.2.1), the causal factors underlying phenomena of smoothly-growing or smoothly-changing demands for different forms of energy have been analysed and discussed at length.

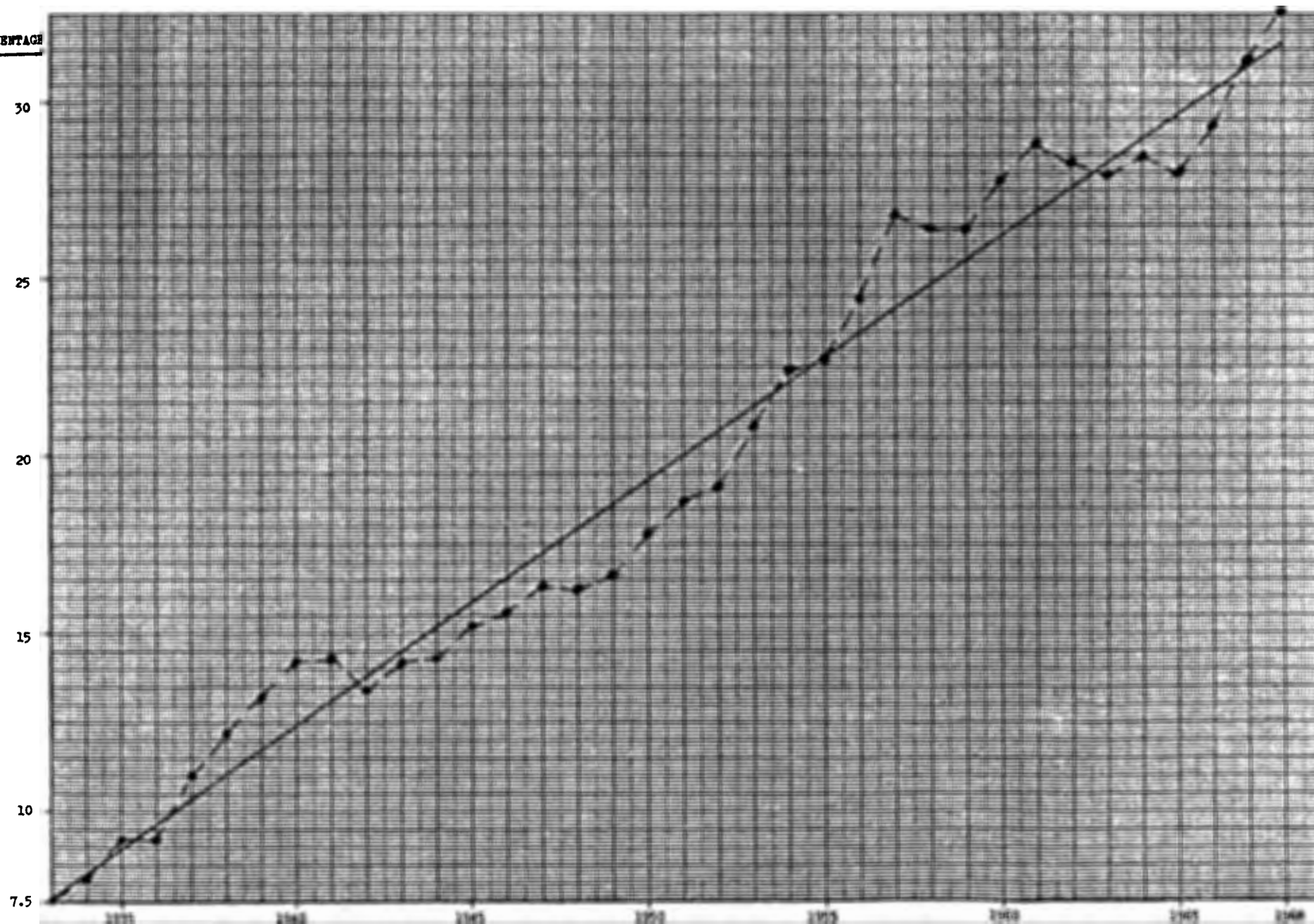
5.3.2.1 Households sector

Figures 16 to 20 provide a graphic illustration of historical trends in the contributions of each form of energy to the total of the households sector. The data used in constructing these graphs are given in Table 41 (page 275).

FIGURE 16: MARKET SHARE OF ELECTRICITY IN HOUSEHOLDS. 1933 - 1968

$$\hat{Y} = -1334 + 0.694X$$

Y - PERCENTAGE



X - YEARS

FIGURE 17: MARKET SHARE OF COAL IN HOUSEHOLDS, 1933 - 1968

$$\bar{F} = (180.1) (0.43023)^{(1.0214)^{X-1933}}$$

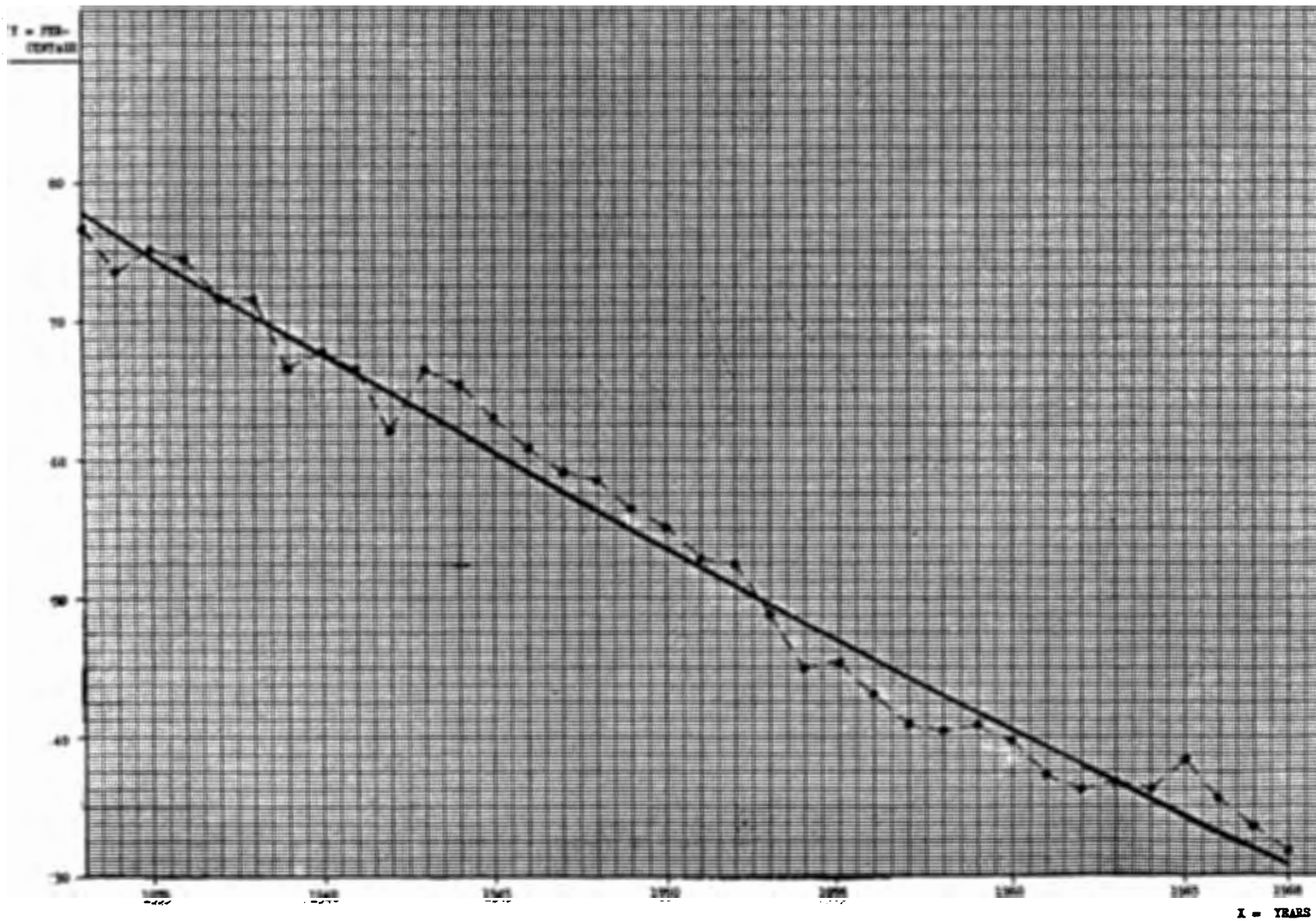
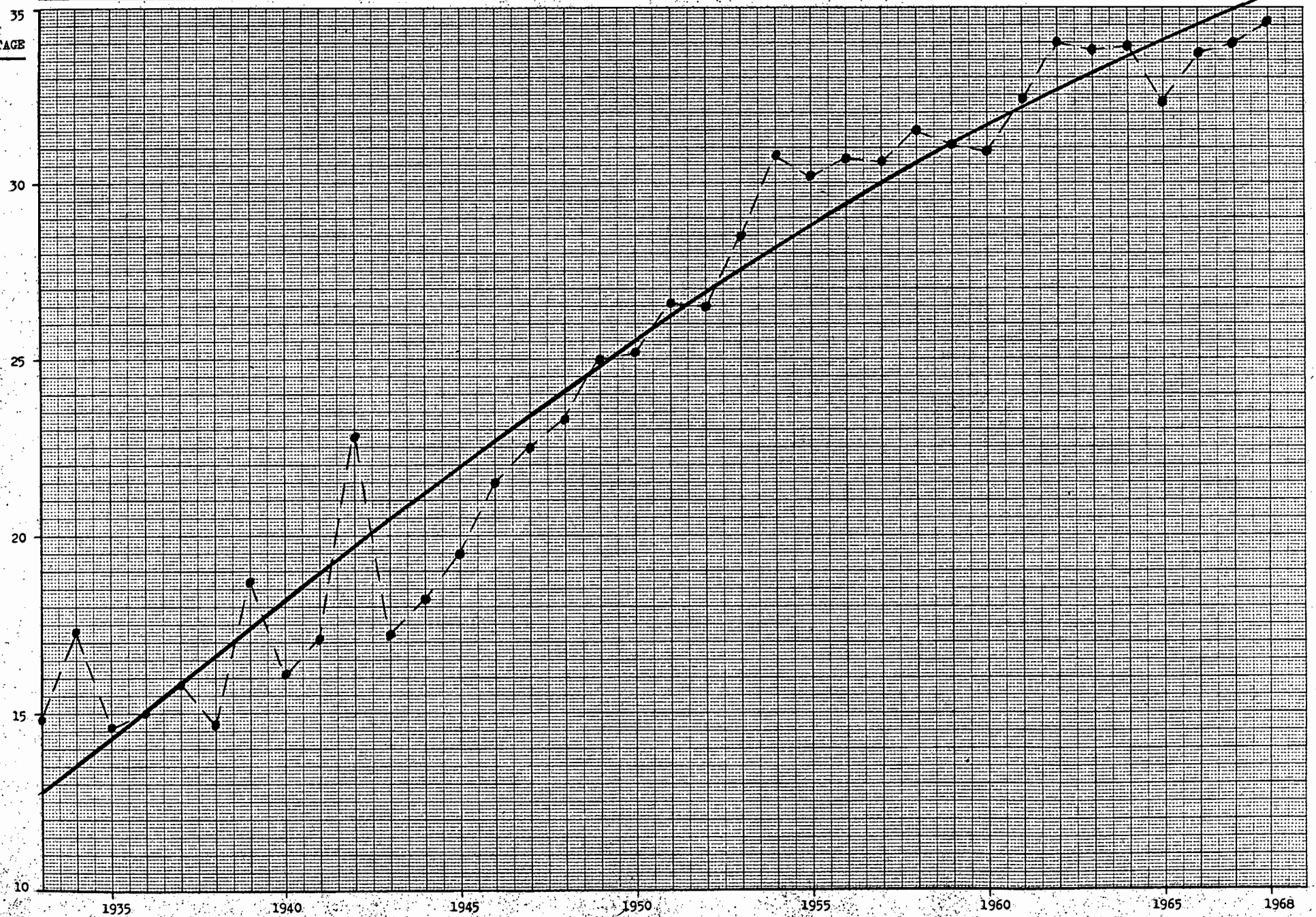


FIGURE 18: MARKET SHARE OF OIL IN HOUSEHOLDS, 1933 - 1968

$$\bar{Y} = (45.5) (0.28035)^{X-1933}$$

Y = PERCENTAGE



X = YEARS

FIGURE 19: MARKET SHARE OF COAL GAS IN HOUSEHOLDS, 1933 - 1968

$$\hat{Y} = 51.329 - 0.0255X$$

Y = PERCENTAGE
2.0

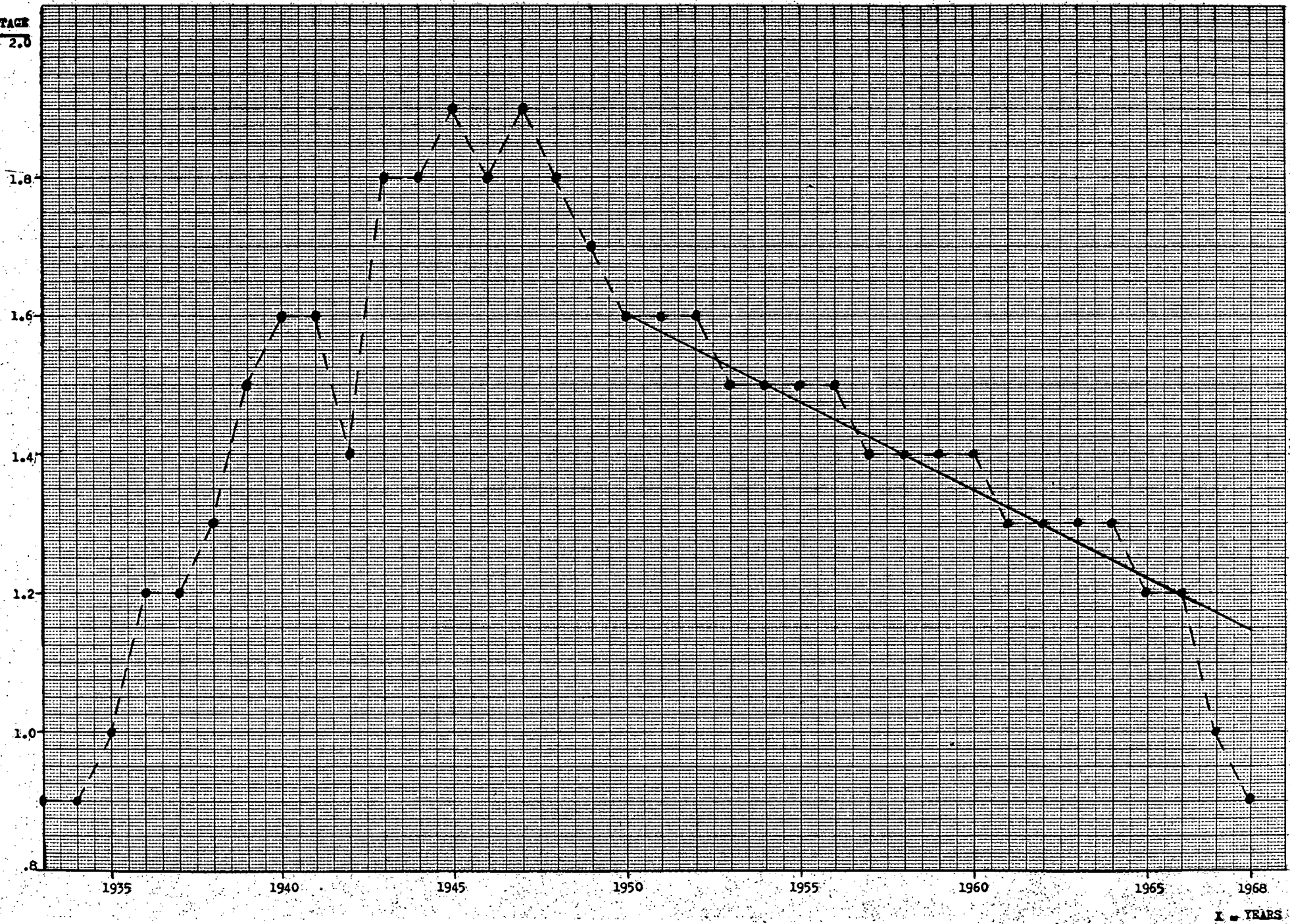
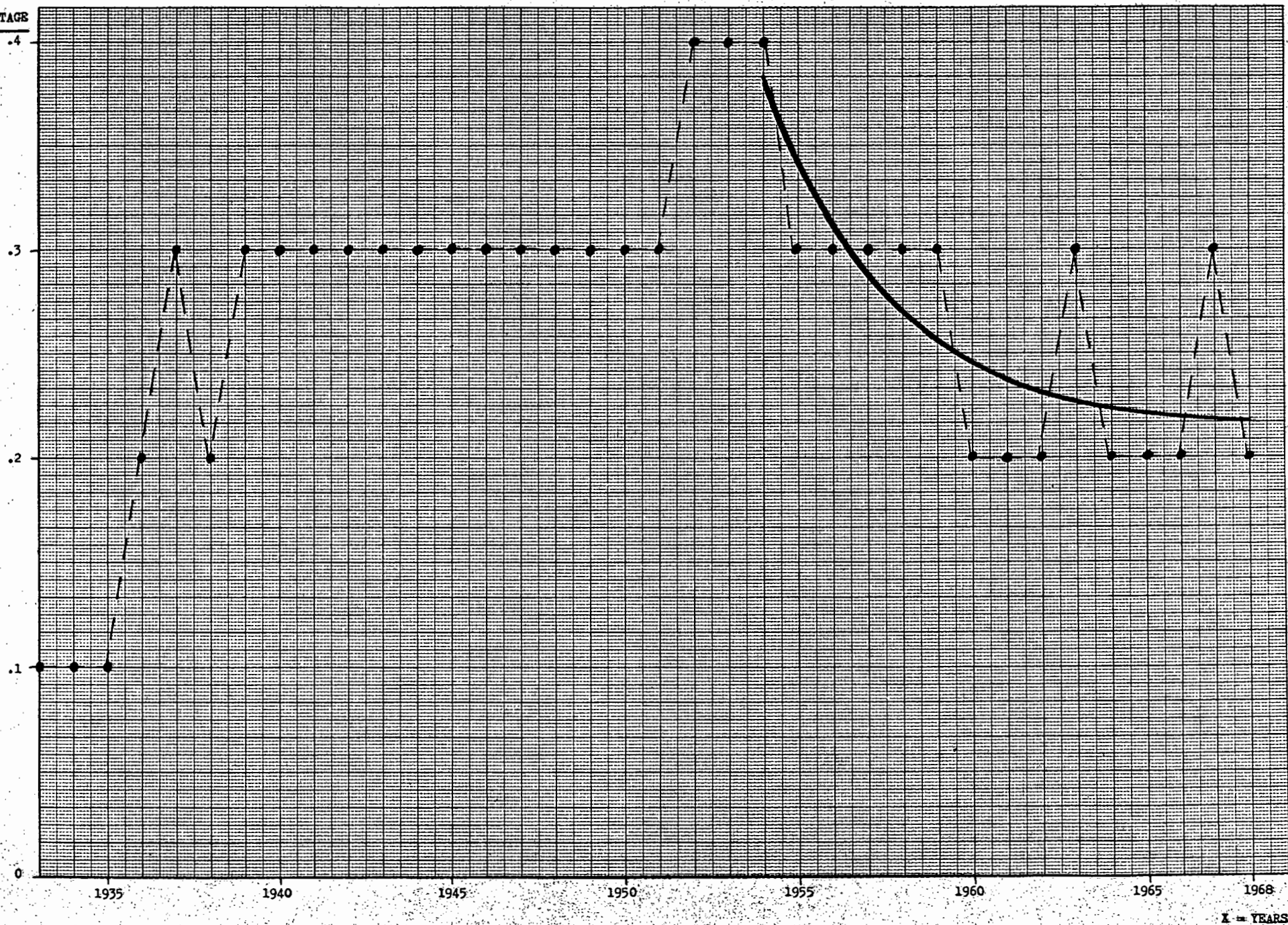


FIGURE 20 : MARKET SHARE OF GAS COKE IN HOUSEHOLDS, 1933 - 1968.

$$\sqrt{Y} = 0.2134 + 0.172 (0.75788)^{X-1954}$$

Y = PERCENTAGE



X = YEARS

For electricity (Fig. 16), the historical observations followed a straight line very closely, indicating that the share of electricity was steadily growing. The trend towards "nobler" forms of energy was already discussed. With constantly rising standards of living, consumer durables, such as domestic electrical appliances, come increasingly within the reach of more consumers.

More and more rural areas are being connected to the electricity supply and, as a result of this, consumers tend to convert to electricity for reasons of cleanliness, versatility and flexibility.

The following straight line was fitted to the historical data:

$$Y = -1334 + 0.694X$$

where Y = market share of electricity

X = year

The amount of coal being used domestically (Fig. 17) is decreasing steadily, mainly as a result of conversion to electricity.

The graph of this time series indicates that a straight line could be fitted, but, on closer inspection, it can be seen that the trend levels off very gradually. This is caused by the fact that coal will never be completely replaced in households. It will always continue to be used by the lower income groups and by consumers close to the coal-fields, where definite price advantages exist. Instead of fitting a straight line which would eventually give coal a zero market holding (in 1990 to be exact), it was decided that a form of the Gompertz curve appeared to be more appropriate.

The calculated relationship assumed the form:

$$Y = (180.1)(0.43023)^{(1.0214)^{X-1933}}$$

where Y = market share of coal

X = year

From Fig. 18, it can be seen that there has been a steady growth in the share of oil in the households sector, particularly due to mechanisation in the farming sector. (In Appendix I, for the year 1968, it can be seen that the farming sector is responsible for about 65 per cent of the petroleum demand in the households sector). Here, too, a levelling off of the market share in latter years is apparent, because of approaching maturity in the mechanisation process.

A Gompertz curve was best found to fit the historical data and would give expression, in the future, to the observations made. The calculated equation is:

$$Y = (45.5)(0.28035)^{(0.955)^{X-1933}}$$

where Y = market share of oil

X = year

The two remaining forms of energy, i.e. coal gas and gas coke (Figures 19 and 20), are the products of the five remaining town gas producers, discussed in Chapter 2 (Section 2.2.6). From the two diagrams it can be seen that the contributions of these two energy forms are very small - in aggregate, about one per cent in 1968.

Relationships were also fitted to a section of the two sets of historical observations, as indicated. For coal gas the following straight line was calculated from 1950 onwards:

$$Y = 51.329 - 0.0255X$$

where Y = market share of coal gas

X = year

A modified exponential was considered appropriate to the trend over the last few years, in the case of gas coke. The following equation resulted:

$$Y = 0.2134 + 0.172 (0.75788)^{X-1954}$$

where Y = market share of gas coke

X = year

Extrapolation of these equations yielded results which were inconsistent with known future developments and were therefore rejected. It was, for instance, already indicated in Section 2.2.6 of Chapter 2 that the tendency is towards conversion from coal to oil as a source of raw material in the manufacture of town gas. It means, of course, that the production of gas coke, the by-product when coal is used as raw material, falls away immediately.

Producers still using coal for the production of town gas include those at Johannesburg, Cape Town and Grahamstown. (Gascor reticulates coal gas to industrial consumers only and is, therefore, not included in the households sector.) The Grahamstown Gas and Coke Company Limited is currently implementing a conversion programme which is to be completed during 1971. Only two remaining producers, i.e. those at Johannesburg and Cape Town will therefore manufacture gas to be consumed in the households sector, after 1971.

It was, therefore, assumed that only one producer, namely the Johannesburg Municipal Gas Works, will still be manufacturing town gas from coal in 1980 and thereafter, owing to its proximity to the coal-fields. Forward estimates on the consumption of coal gas and gas coke, in the households sector, are therefore identical to the present sales of the Johannesburg Municipal Gas Works, as indicated in Table 55.

TABLE 55: FORECAST DEMAND PATTERN OF ENERGY IN HOUSEHOLDS SECTOR, 1968 - 2000

(10⁶ MEGAJOULES)

	1968		1980		1990		2000	
	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ELECTRICITY	17,464	32.6	41,958	40.8	80,174	47.2	147,425	52.6
COAL	16,960	31.7	19,258	18.7	18,321	10.8	15,136	5.4
OIL	18,500	34.6	41,193	40.0	70,570	41.6	117,166	41.8
COAL GAS	474	0.9	456	0.4	456	0.3	456	0.2
OTHER GAS								
COKE								
GAS COKE	118	0.2	118	0.1	118	0.1	118	0.0
TOTAL	53,516	100.0	102.983	100.0	169.639	100.0	280,301	100.0

For electricity, coal and oil, the relationships discussed above were extrapolated for the years 1980, 1990 and 2000. The total market share, for all forms of energy (including coal gas and gas coke), so established, was 98.4 per cent for 1980, 99.7 per cent for 1990 and 102.7 per cent for 2000. The total of all market shares can obviously not be more than 100 per cent and since differences obtained were small, they have been prorated over all forms of energy. The final results are presented in Table 55. The sectoral energy forecasts are of course obtained from Section 5.3.1.1.

5.3.2.2 Industrial sector

Figures 21 to 27 depict the historical progression of the market shares of all energy-producing agents in the industrial sector. The data are given in Table 42 (page 276).

The rapid growth in market share of electricity in the industrial sector (Fig.21), in the post-war period, must be seen as the natural outflow of the pace with which industrialisation has taken place in the South African economy over this period. There is no substitute for the electrical motor in the industrial sector. With the assumption of further industrialisation of the economy, it must accordingly be expected that the contribution of electricity to the energy demands of the industrial sector will continue to increase.

It was found that the following straight line best fits the observations from 1952 onwards:

$$Y = -876.2 + 0.454X$$

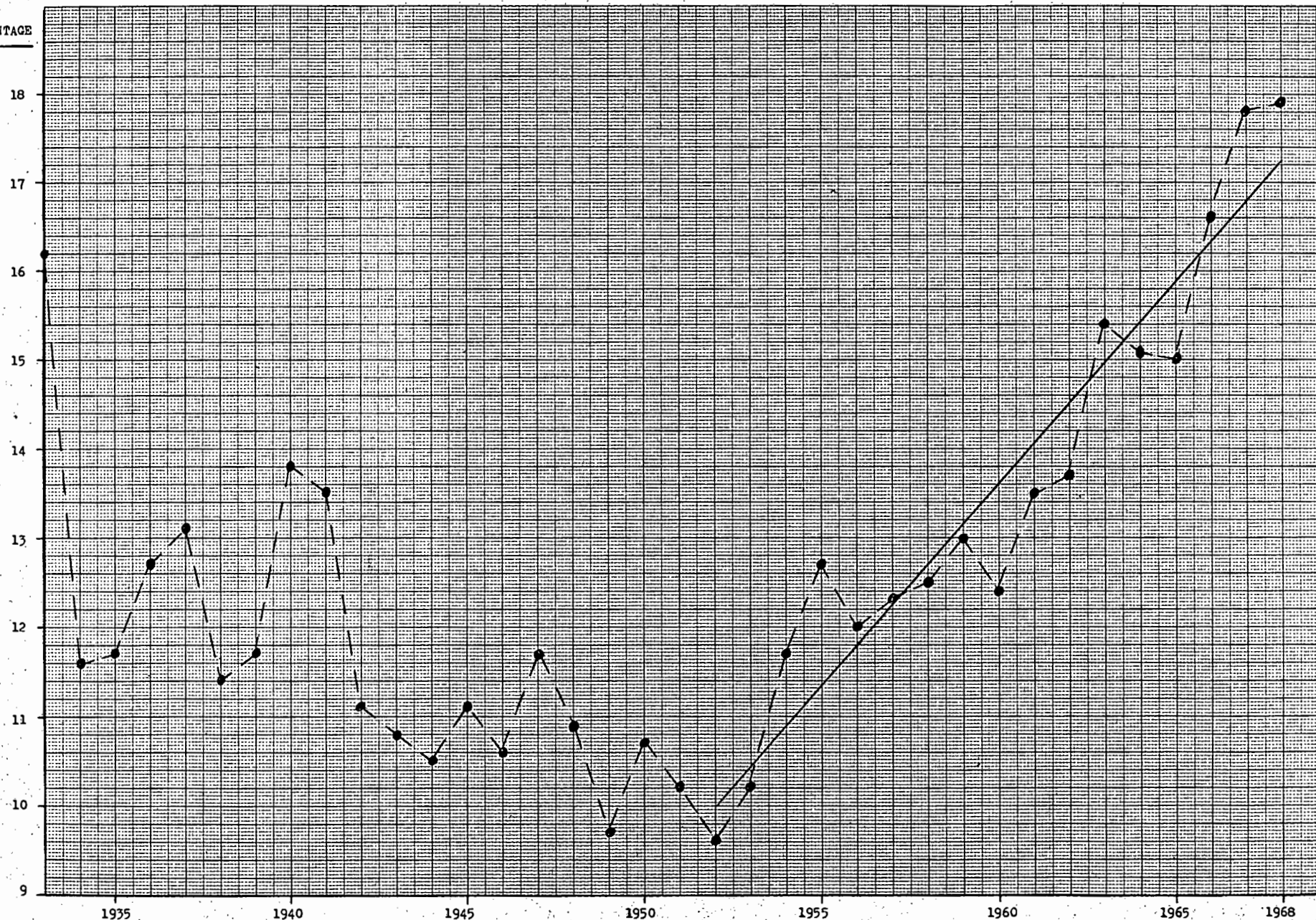
where Y = market share of electricity

X = year

FIGURE 21: MARKET SHARE OF ELECTRICITY IN INDUSTRY, 1933 - 1968

$$\bar{Y} = -876.2 + 0.454X$$

Y = PERCENTAGE



X = YEAR

FIGURE 22: MARKET SHARE OF COAL IN INDUSTRY, 1933 - 1968

$$\bar{Y} = 1126.9 - 0.554X$$

Y = PERCENTAGE

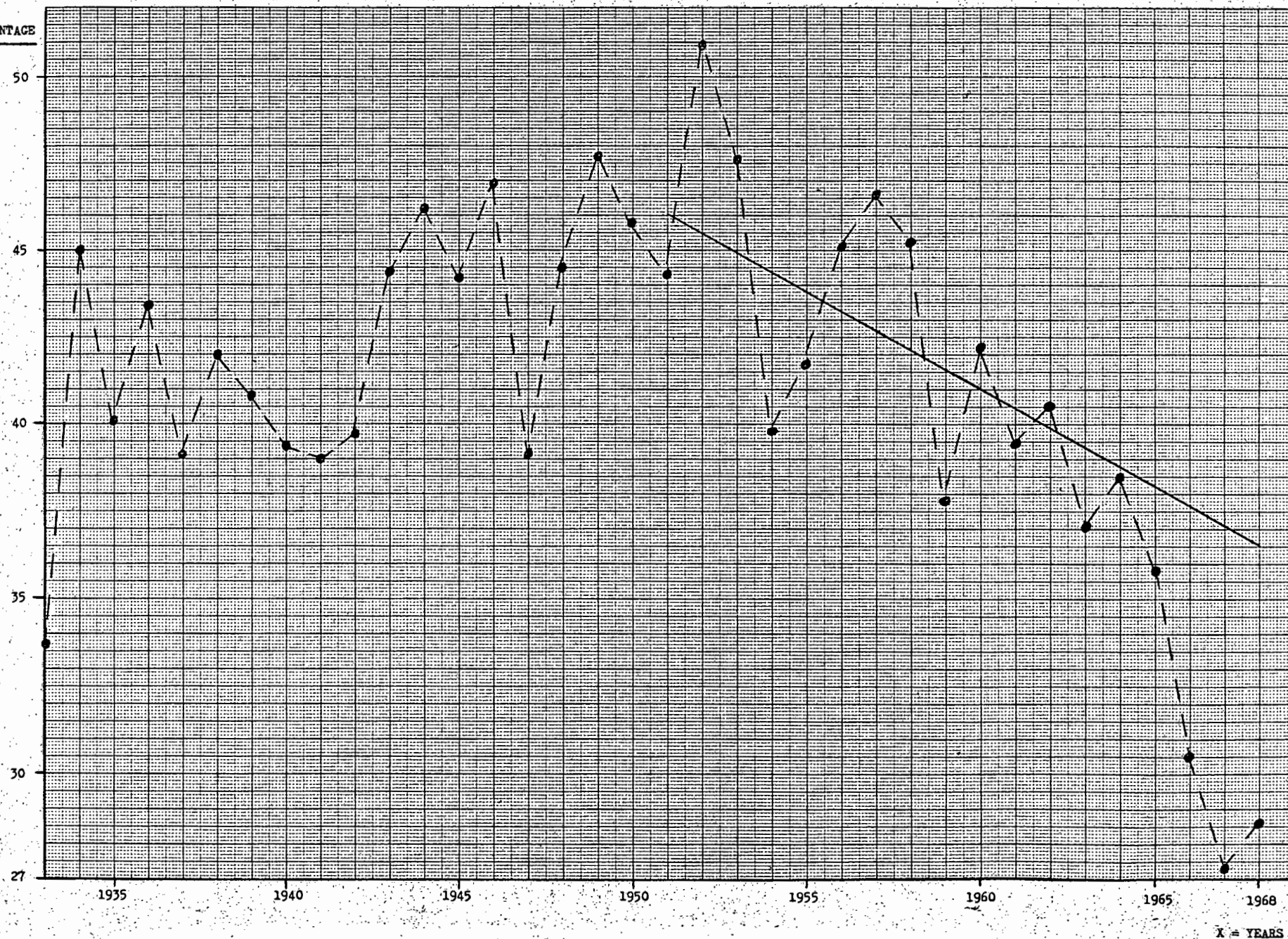
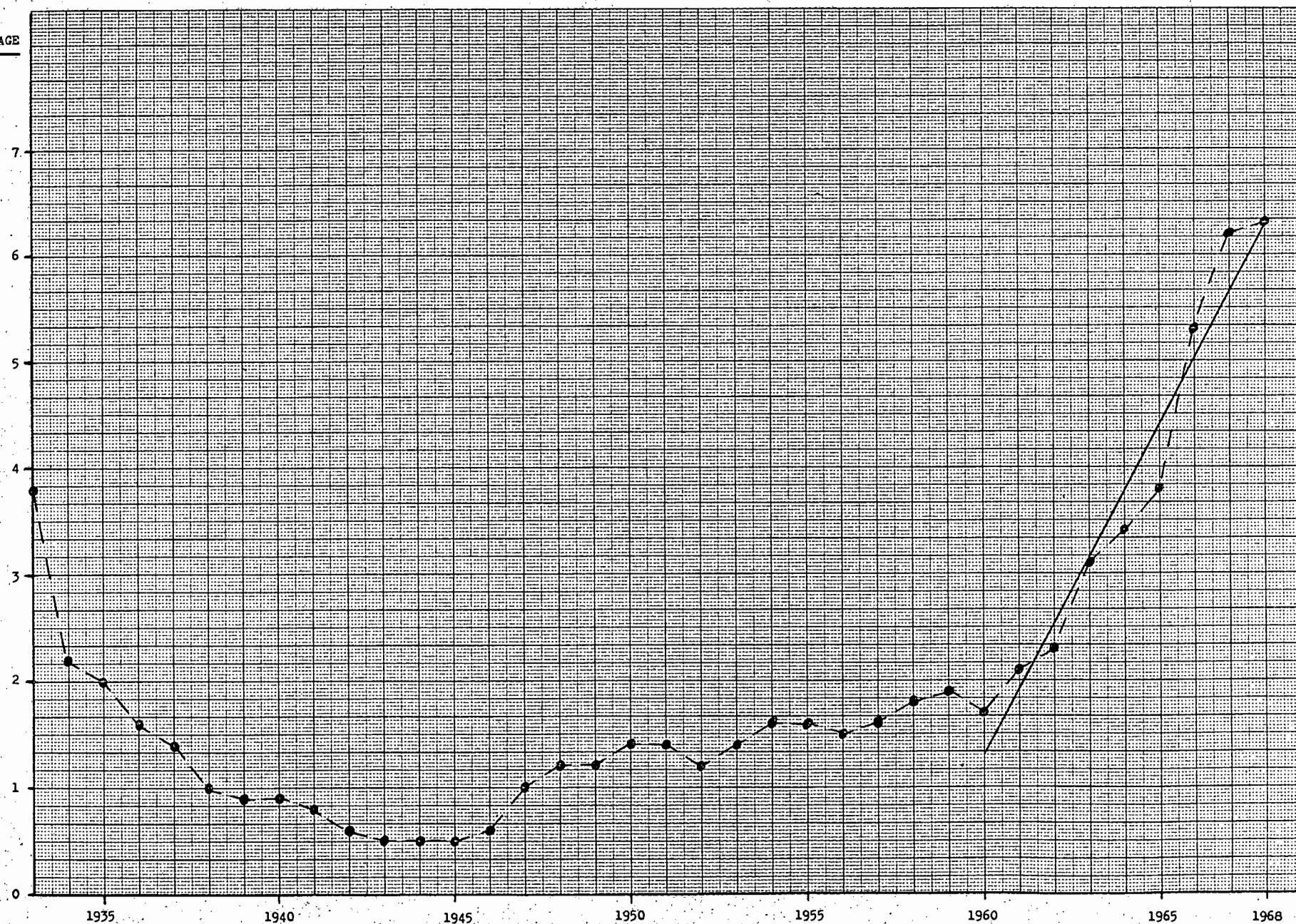


FIGURE 23: MARKET SHARE OF OIL IN INDUSTRY, 1933 - 1968

$$\bar{Y} = -1219.18 + 0.623X$$

Y = PERCENTAGE



X = YEARS

FIGURE 24: MARKET SHARE OF COAL GAS IN INDUSTRY, 1933 - 1968

PERCENTAGE

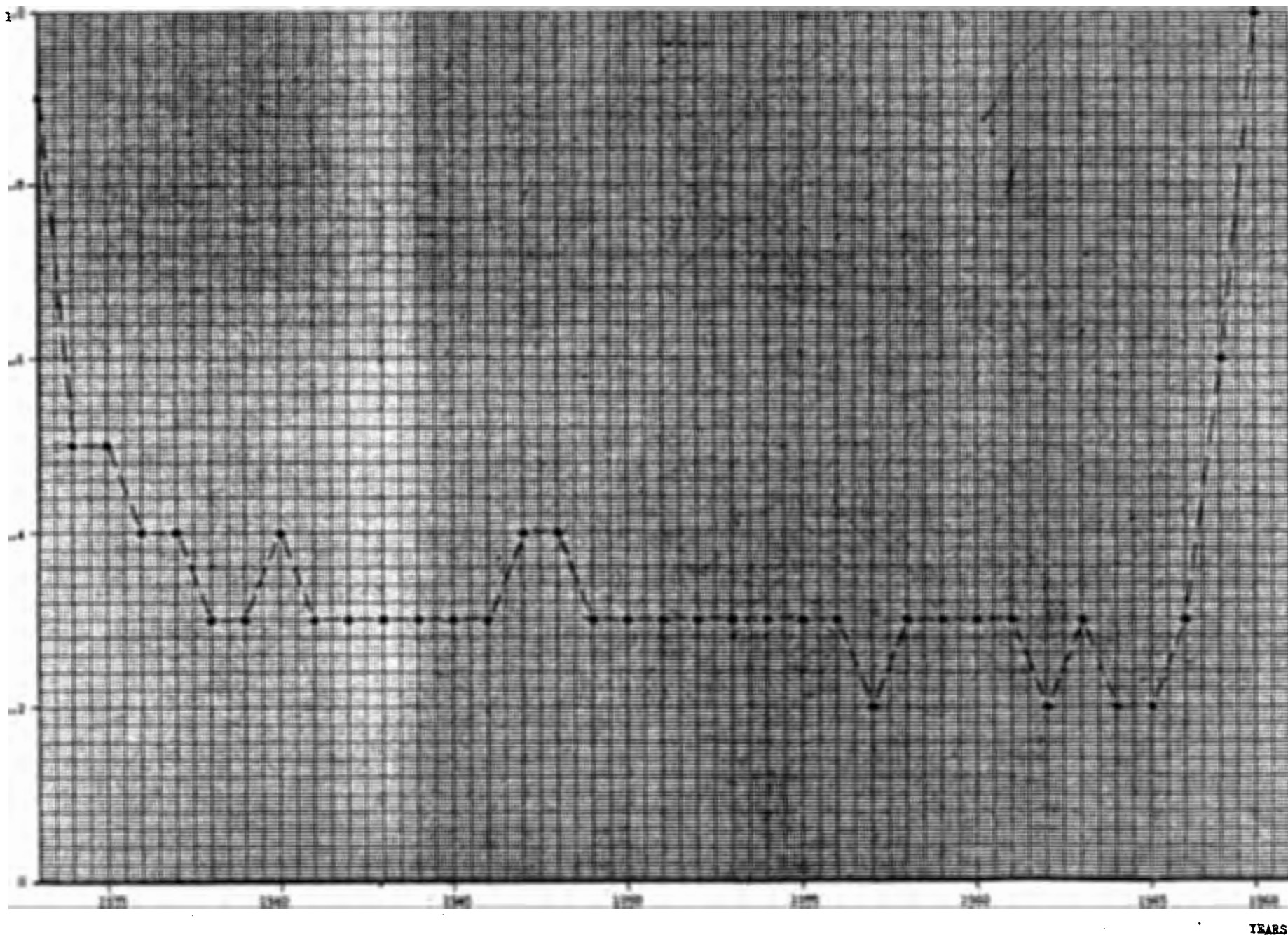


FIGURE 25: MARKET SHARE OF OTHER GAS IN INDUSTRY, 1933 - 1968

$$\bar{Y} = -172.1 + 0.0943\bar{X}$$

Y = PERCENTAGE

14.0

13.0

12.0

11.0

10.0

9.0

8.0

1935

1940

1945

1950

1955

1960

1965

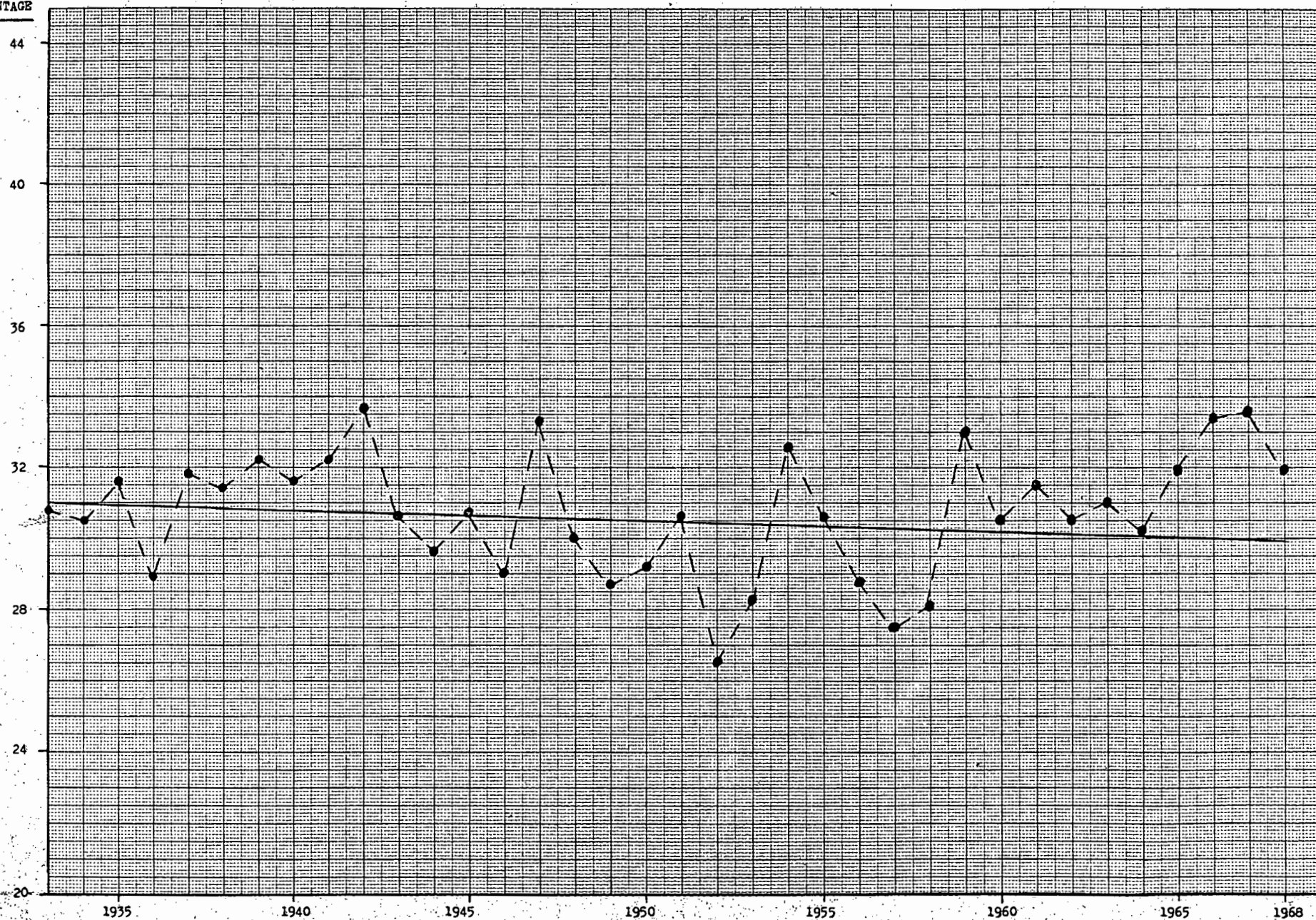
1968

X = YEAR

FIGURE 26: MARKET SHARE OF COKE IN INDUSTRY, 1933 - 1968

$$\bar{Y} = 90.3 - 0.0305X$$

Y = PERCENTAGE

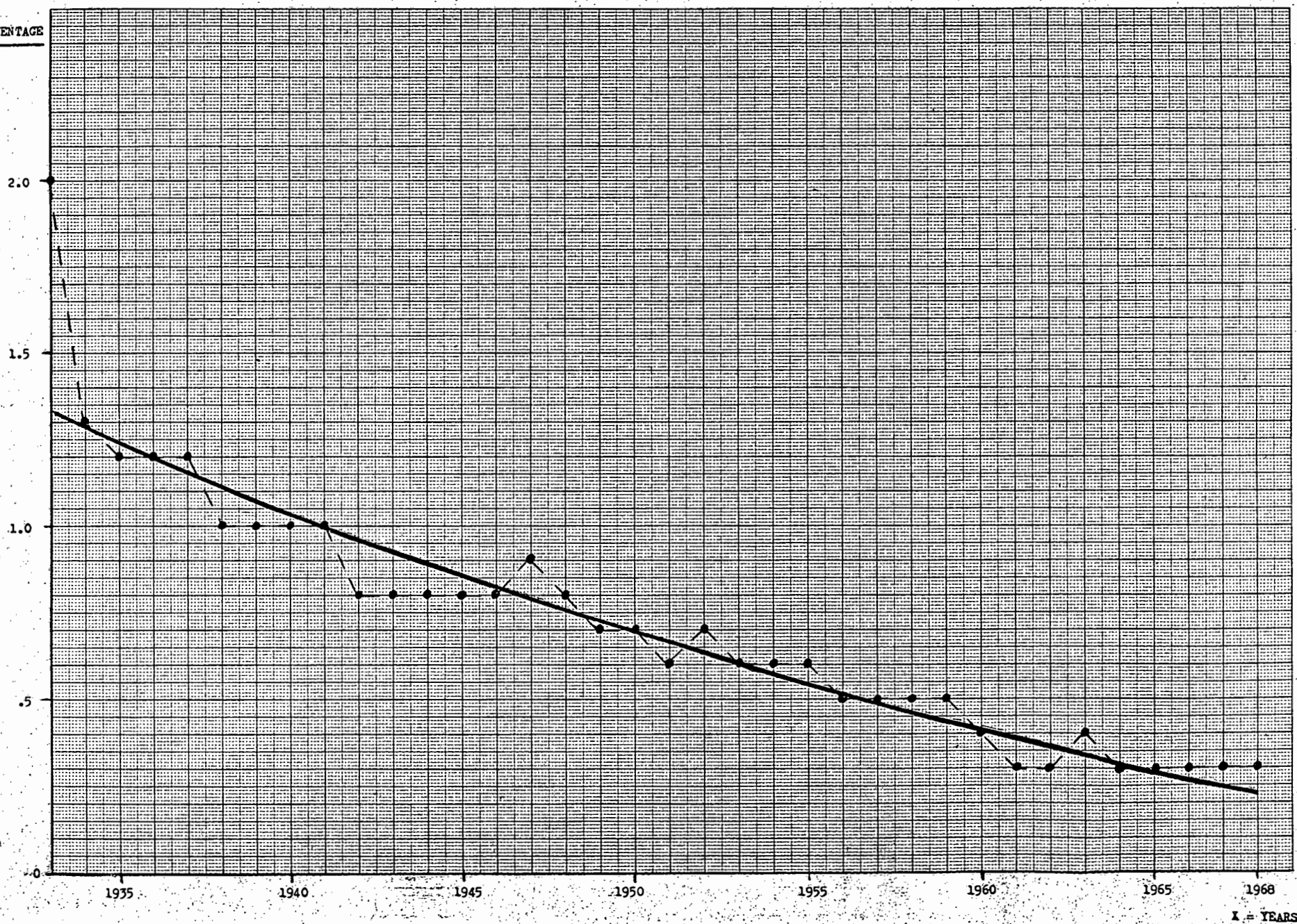


X = YEARS

FIGURE 27: MARKET SHARE OF GAS COKE IN INDUSTRY, 1933 - 1968

$$\bar{Y} = -0.79 + (2.12)(0.78)^{X-1933}$$

Y = PERCENTAGE



The market shares of electricity for the forecast years have therefore been calculated on the basis of this relationship and are given in Table 56.

A straight line was considered appropriate to the historical market shares of coke, as indicated in Fig. 26. The resultant equation was:

$$Y = 90.3 - 0.0305X$$

where Y = market share of coke

X = year

Forward market shares of coke established from the equation are given in Table 56.

A straight line was similarly fitted in the case of other gas, (Fig.25), for the period after 1949, and future market shares derived from the equation. This assumed the following form:

$$Y = -172.1 + 0.0943X$$

where Y = market share of other gas

X = year

In the case of gas coke, (Fig. 27), the following modified exponential relationship fitted the historical observations reasonably well:

$$Y = -0.79 + (2.12)(0.78)^{X-1933}$$

where Y = market share of gas coke

X = year

TABLE 56: FORECAST DEMAND PATTERN OF ENERGY IN INDUSTRIAL SECTOR, 1968 TO 2000

(10⁶ MEGAJOULES)

	1968		1980		1990		2000	
	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ELECTRICITY	41,063	17.9	112,086	22.7	248,929	27.2	507,136	31.8
COAL	65,660	28.6	64,954	13.2	90,830	9.9	129,241	8.1
OIL	14,492	6.3	93,106	18.8	154,914	16.9	216,383	13.6
COAL GAS	2,255	1.0	4,938	1.0	9,152	1.0	15,948	1.0
OTHER GAS	32,038	14.0	72,090	14.6	142,768	15.6	263,137	16.5
COKE	73,079	31.9	146,156	29.6	268,148	29.3	462,482	29.0
GAS COKE	580	0.3	440	0.1	440	0.1	440	0.0
TOTAL	229,167	100.0	493,770	100.0	915,181	100.0	1,594,767	100.0

Extrapolation of this relationship again yielded unrealistic results, in terms of the comments made on this form of energy in the previous sector. Future values of gas coke are therefore again assumed to be equivalent to the present sales (in the industrial sector) of the Johannesburg Municipal Gas Works.

The market share of coal gas (Fig. 24), which for many years fluctuated within narrow limits, suddenly increased sharply after 1965. This was, of course, caused by the advent of Gascor, the output of which is sold solely in the industrial sector. It can be seen in the diagram that it was impossible to project future market shares on the basis of a reasonable historical relationship. The company concerned was therefore approached to give an indication of their future plans and, after studying these, it was decided to maintain the market share of coal gas at 1 per cent in future years, as shown in Table 56.

Straight lines were also fitted to certain observation periods of the historical market shares of coal and oil as indicated in Figures 22 and 23. For coal, the following relationship was obtained.

$$Y = 1126.9 - 0.554X$$

where Y = market share of coal

$$X = \text{year}$$

For oil, the appropriate equation was:

$$Y = -1219.8 + 0.623X$$

where Y = market share of oil

$$X = \text{year}$$

Extrapolation of the last two relationships yielded inconsistent results and it became clear that a more thorough investigation was required into the interrelationships of market shares of the different forms of energy.

A relative price analysis was therefore carried out on coal, oil and electricity, the three major sources of energy which could possibly be involved in cross-substitution in the industrial sector.

Table 57 lists price indices for electricity, coal and oil, and also shows to what extent shifts have occurred in the relative prices of the different sources by expressing their ratios.

The industrial price index for electricity was constructed from column (4) of Table 23.

It has not been possible to construct a price series for coal sold industrially. The composite price index for coal sold in all sectors, (excluding the conversion sector) has therefore been used for this purpose (column (5), Table 20). Discussion with the various coal authorities indicated that there was no reason for believing that sectoral price trends would be very different from the total.

The series on oil prices were constructed from data kindly made available by Mobil Oil S.A. (Pty) Limited. This was done by calculating the annual average sales realizations of the Company concerned, per unit volume, of each of the oil products listed in Table 24. The average annual sales realizations for each product, thus obtained, were weighted by their respective historical volumes, appearing in Table 24. The Company in question is one of the biggest oil companies in South Africa so that the price series, thus constructed, can be considered representative of the industry as a whole. The oil price index is therefore also

TABLE 57: RELATIVE PRICES AND VOLUMES OF ELECTRICITY, COAL AND OIL IN THE INDUSTRIAL ENERGY SECTOR

	INDEX OF ELECTRICITY PRICES (INDUSTRIAL SECTOR)	INDEX OF COAL PRICES	INDEX OF OIL PRICES	RELATIVE PRICE INDEX OIL COAL	RELATIVE PRICE INDEX COAL ELECTRICITY	RELATIVE PRICE INDEX ELECTRICITY OIL	VOLUME RATIO: OIL COAL	VOLUME RATIO: COAL ELECTRICITY	VOLUME RATIO: ELECTRICITY OIL
	(1958 = 100) (1)	(1958 = 100) (2)	(1958 = 100) (3)	(4) = $\frac{(3)}{(2)}$	(5) = $\frac{(2)}{(1)}$	(6) = $\frac{(1)}{(3)}$	(7)	(8)	(9)
1939		44.3	56.6	1.28			0.022	3.49	13.00
1940		45.5	68.3	1.50			0.023	2.86	15.33
1941		46.2	75.5	1.63			0.021	2.89	16.87
1942		46.7	83.4	1.79			0.015	3.58	18.50
1943		43.7	85.7	1.96			0.011	4.11	21.60
1944		45.4	84.9	1.87			0.011	4.40	21.00
1945		48.0	77.0	1.60			0.011	3.98	22.20
1946		52.8	67.9	1.29			0.013	4.42	17.67
1947		54.7	61.9	1.13			0.026	3.34	11.70
1948		55.8	69.1	1.24			0.027	4.08	9.08
1949	63.7	67.1	69.8	1.04	1.05	0.91	0.025	4.92	8.08
1950	64.9	75.4	84.5	1.12	1.16	0.77	0.031	4.28	7.64
1951	68.7	70.0	93.2	1.33	1.01	0.74	0.032	4.34	7.29
1952	71.0	71.2	97.4	1.37	1.00	0.73	0.024	5.30	8.00
1953	81.8	78.2	96.6	1.24	0.95	0.85	0.029	4.67	7.29
1954	88.1	81.4	97.0	1.19	0.92	0.91	0.040	3.40	7.31
1955	90.6	84.7	94.3	1.11	0.93	0.96	0.038	3.28	7.94
1956	90.6	90.4	94.0	1.03	0.99	0.96	0.033	3.76	8.00
1957	94.2	94.5	98.5	1.04	1.00	0.96	0.034	3.79	7.69
1958	100.0	100.0	100.0	1.00	1.00	1.00	0.040	3.62	6.94
1959	106.2	102.9	101.9	0.99	0.96	1.04	0.050	2.91	6.84
1960	109.7	104.7	103.8	0.99	0.95	1.06	0.040	3.40	7.29
1961	112.2	105.8	103.4	0.97	0.94	1.09	0.053	2.92	6.43
1962	110.6	113.6	106.0	0.93	1.02	1.04	0.057	2.96	5.96
1963	110.7	118.3	103.8	0.87	1.06	1.07	0.084	2.41	4.97
1964	111.2	119.8	104.2	0.86	1.07	1.07	0.088	2.55	4.44
1965	109.3	124.7	99.6	0.79	1.14	1.10	0.106	2.39	3.95
1966	115.9	126.4	99.2	0.78	1.09	1.17	0.174	1.84	3.13
1967	121.8	129.8	99.6	0.76	1.06	1.22	0.227	1.53	2.87
1968	125.1	135.5	100.0	0.73	1.08	1.25	0.220	1.60	2.84

a composite index.

Ratios of the various price indices were calculated as shown in Table 57. The applicable volume ratios were also obtained by using the data in Table 37.

Relative price and volume observations, corresponding to each historical year, were plotted on scatter diagrams, as shown in Figures 28, 29 and 30.

Figure 28 provides an indication of the extent to which coal has been displaced by oil in the industrial sector and shows the relationship between the equivalent volume ratios of the two forms of energy and their respective price ratios, over the period 1939 to 1968. A hyperbolic function, the classic relationship quantifying the substitution process was fitted to the observations. The equation assumed the form:

$$Y = \frac{0.01085}{X - 0.6744}$$

where

$$Y = \frac{\text{Oil Volume}}{\text{Coal Volume}}$$
$$X = \frac{\text{Oil Price}}{\text{Coal Price}}$$

Further investigations revealed that the two fuels are really in competition for the generation of heat in the industrial sector. Study of the demand pattern for oil in the industrial sector (see Appendix I) indicates that the use of the heavier type of furnace oil is growing rapidly at the expense of coal.

It is clear that there has been a dramatic shift in the prices of oil and coal in favour of oil, resulting in significant substitution of coal by (mainly) heavy furnace oil. The relationship in Fig. 28 also seems to suggest that the stage of rapid substitution of coal by oil

FIGURE 28: INDUSTRIAL SECTOR, RELATIVE PRICES AND VOLUMES OIL AND COAL, 1939 - 1968.

$$\hat{r} = \frac{0.01085}{x - 0.6744}$$

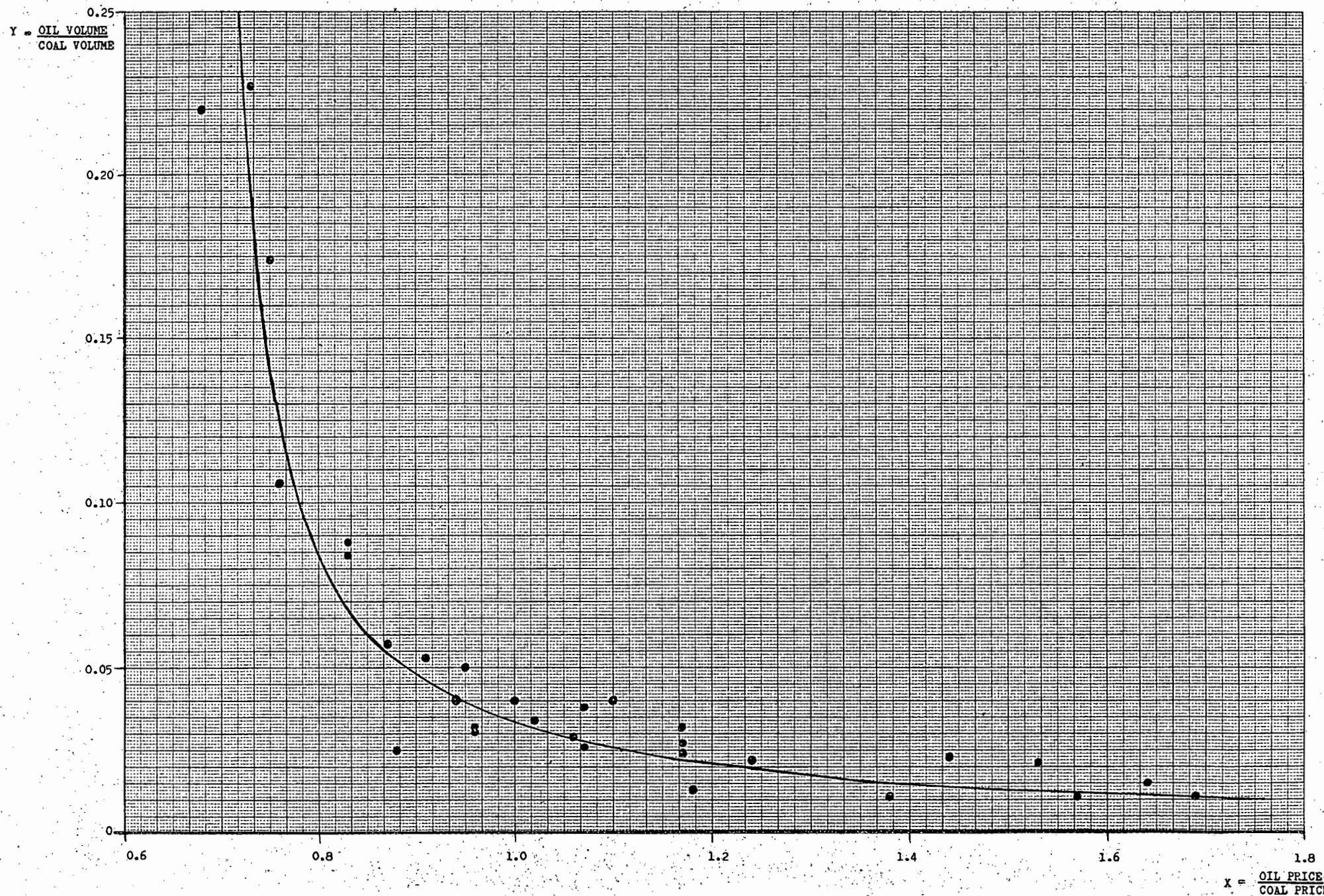


FIGURE 29: INDUSTRIAL SECTOR, RELATIVE PRICES AND VOLUMES COAL AND ELECTRICITY, 1949 - 1968

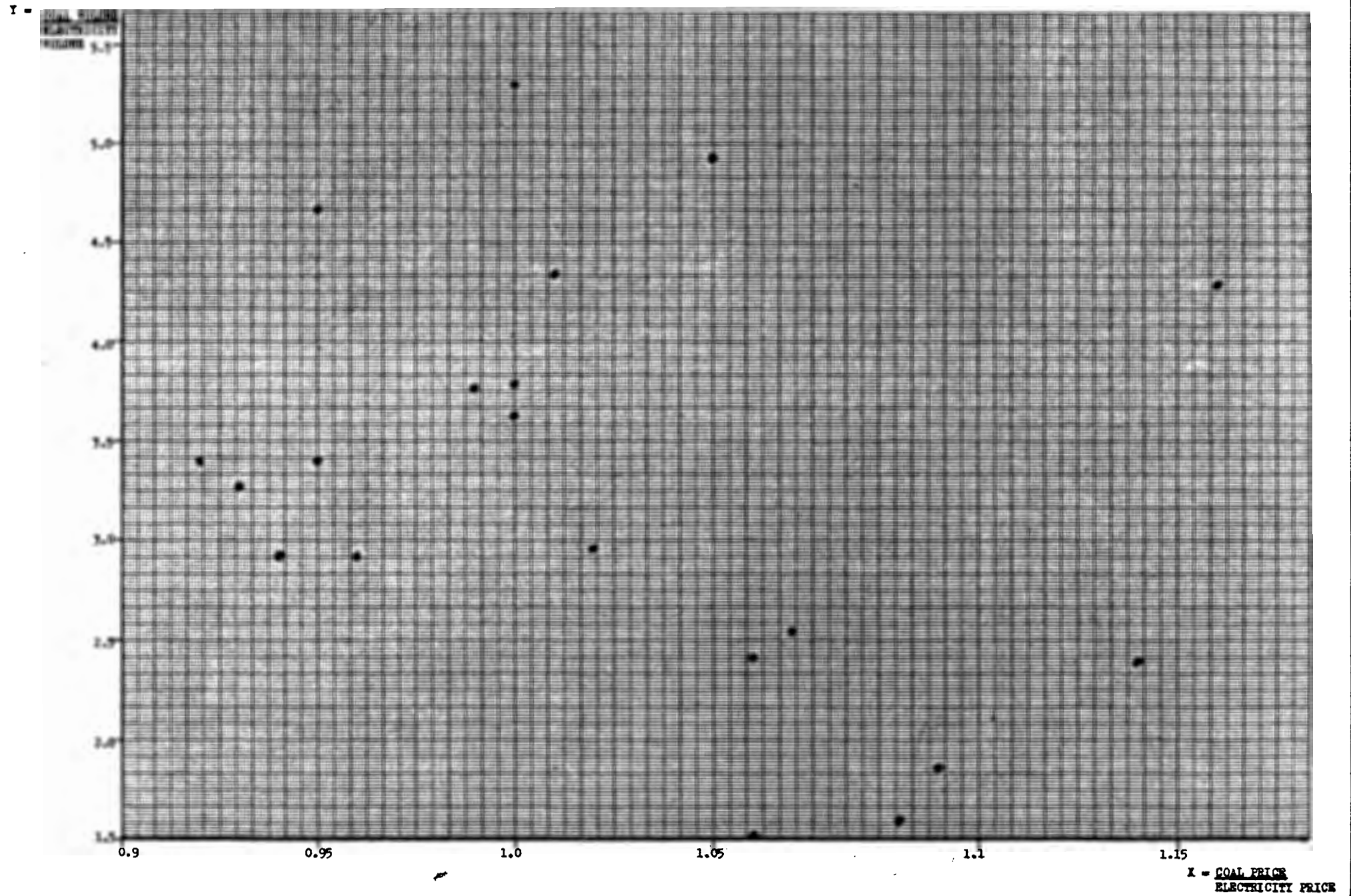
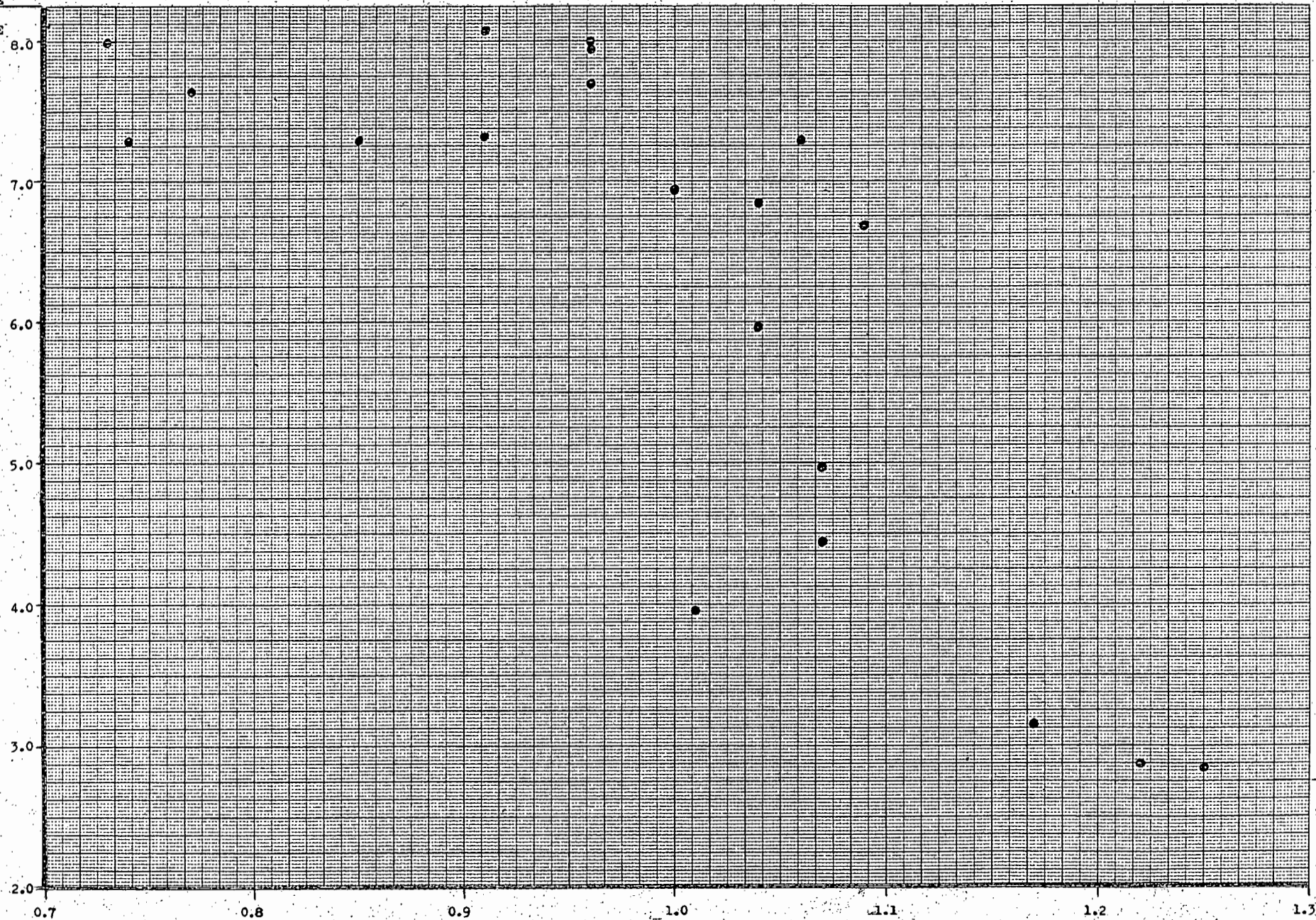


FIGURE 30: INDUSTRIAL SECTOR, RELATIVE PRICES AND VOLUMES ELECTRICITY AND OIL, 1949 - 1968

Y = ELECTRICITY
VOLUME
OIL
VOLUME



X = ELECTRICITY PRICE
OIL PRICE

has now been reached and that parity in prices, on the average, has been achieved.

From the relationship, it appears that oil will eventually displace all coal used in the industrial sector. This is, of course, not so. It is known that furnace oil tends to displace coal in localities far from the coal-fields, such as in the coastal areas where the price of coal is high and amounts to more than 3 times the pithead price. The substitution trend indicated, therefore, really shows the displacement of coal by oil in the coastal regions.

The analysis was accordingly carried through on a geographical basis and it was found that oil will continue to displace coal rapidly in coastal regions, that the process of displacement has already reached an advanced stage, and that it will be completed during the next few years and certainly before 1980. Cost studies also indicated that it will take a long time before furnace oil will be able to attack the industrial coal market (significantly) in the inland areas closer to the coal-fields.

The combined volume forecasts of the two fuels, thus derived, were marginally different from the forecasts implied by subtracting the volumes of the other sources (already rationalised) from the total. Their respective volumes have therefore been prorated to equal the difference, resulting in the market shares indicated in Table 56.

Figures 29 and 30 are also included, for interest's sake. It shows that no significant substitution tendencies, based on price consideration, are apparent between other combinations of the three industrial sources of energy.

It may also be of interest to note that the same relative price analysis was carried out (for the three sources of energy discussed) in the other sectors, i.e. in the households, mining and transport sectors. For the sake of brevity, the scatter diagrams have not been included. The significant result was, however, that no substitution trends on price grounds were found to be present. Substitution which has taken place in other sectors has occurred for reasons other than price.

The forecasts for forward years of total energy consumption in the industrial sector are of course obtained from Table 50.

5.3.2.3. Mining sector

The data on the historical market shares of electricity, coal and oil in the mining sector, as provided in Table 43, are presented in graphic form in Figures 31, 32 and 33.

Modified exponential relationships were fitted to the historical series, or parts of it, as shown in the diagrams.

For electricity, the equation found was:

$$Y = 74.4 - 44.366 (0.92215)^{X-1948}$$

where Y = market share of electricity

X = year

For coal, the following relationship was obtained:

$$Y = 23.42 + 45.993 (0.9247)^{X-1948}$$

where Y = market share of coal

X = year

FIGURE 31: MARKET SHARE OF ELECTRICITY IN MINING 1933 - 1968

$$\bar{Y} = 74.4 - 44.366 (0.92215)^{X-1948}$$

Y = PER-
CENTAGE

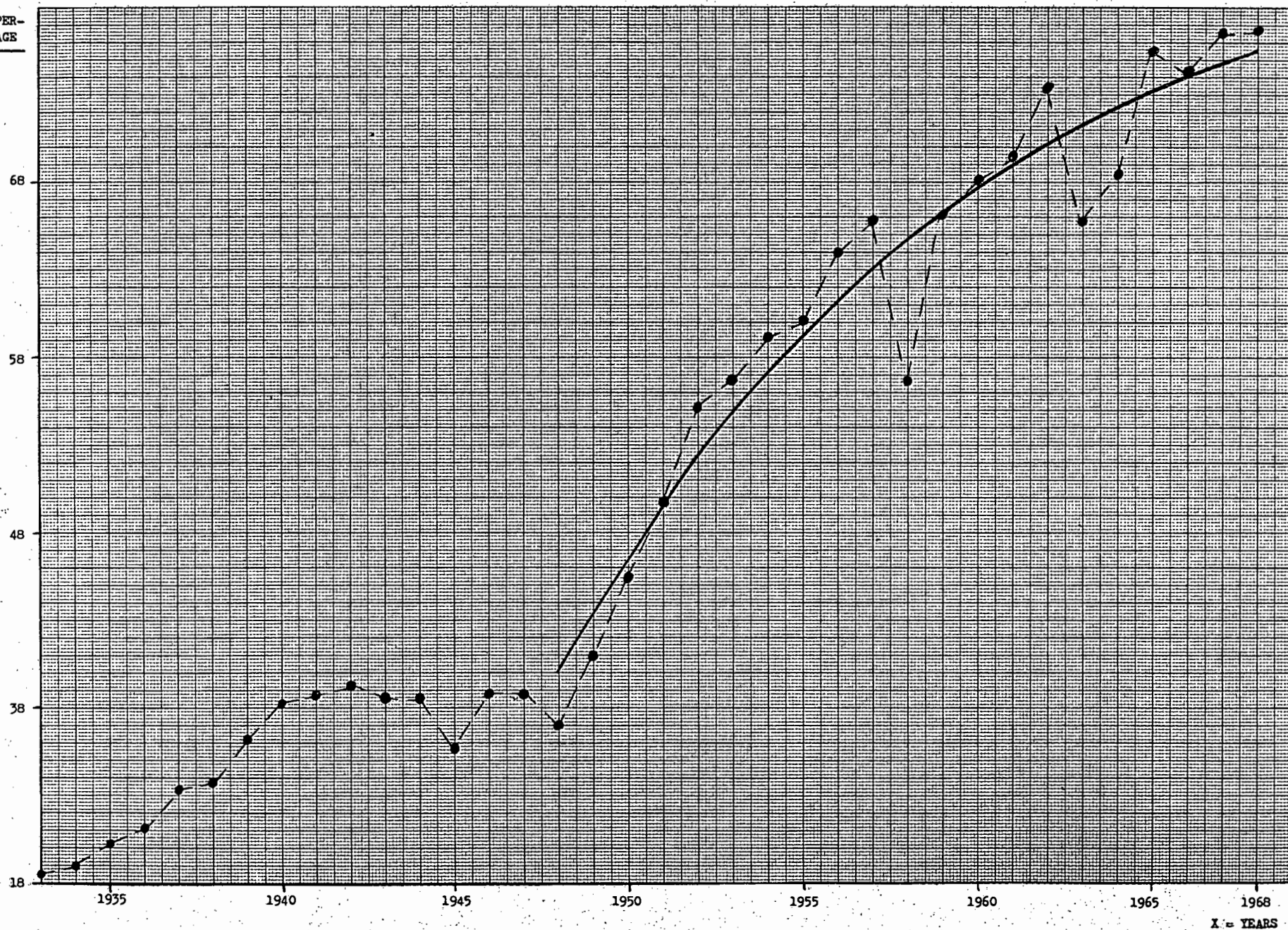


FIGURE 32: MARKET SHARE OF COAL IN MINING, 1933 - 1968

$$\hat{Y} = 23.42 + 45.993 (0.9247)^{X-1948}$$

Y = PERCENTAGE

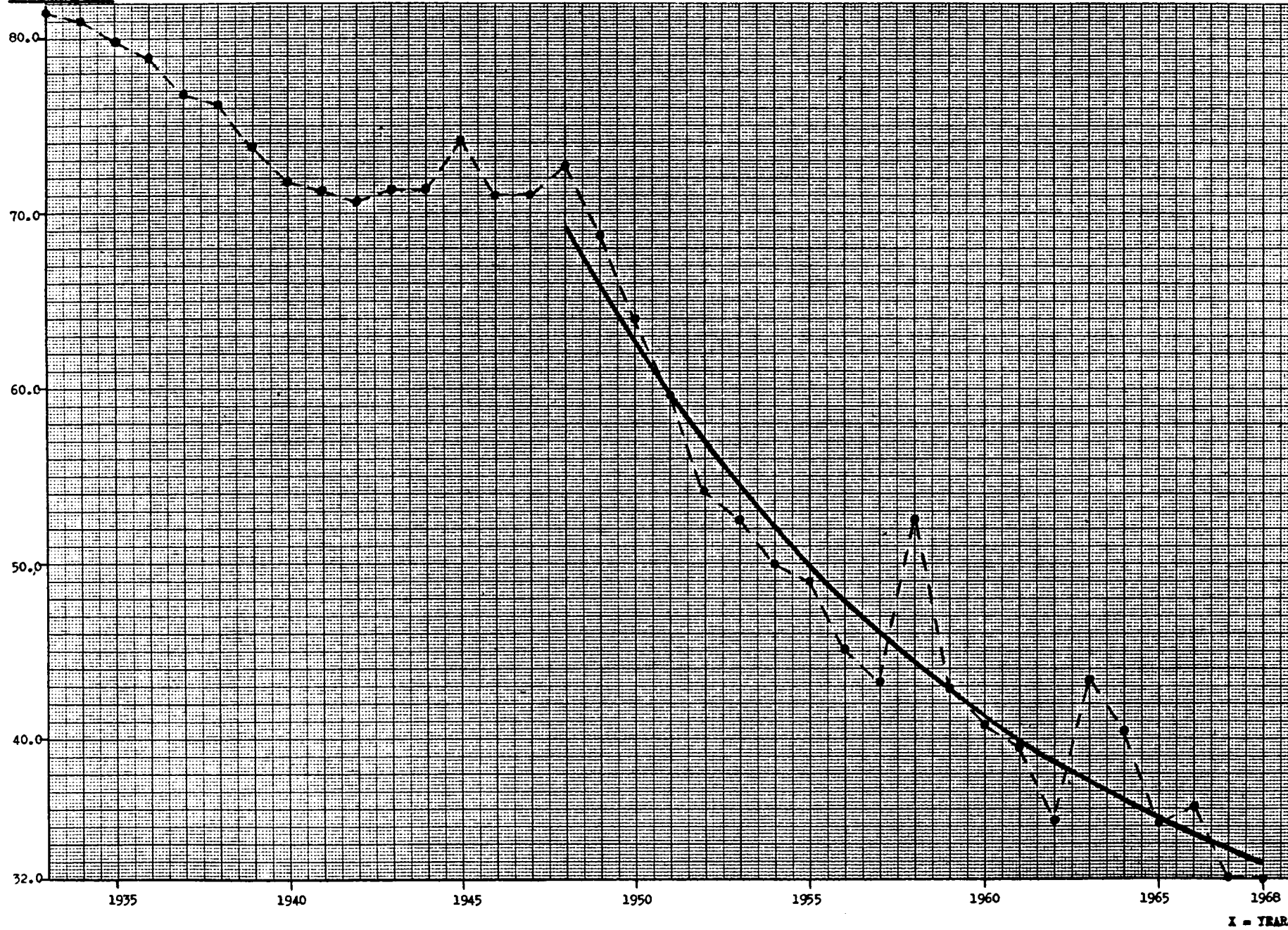
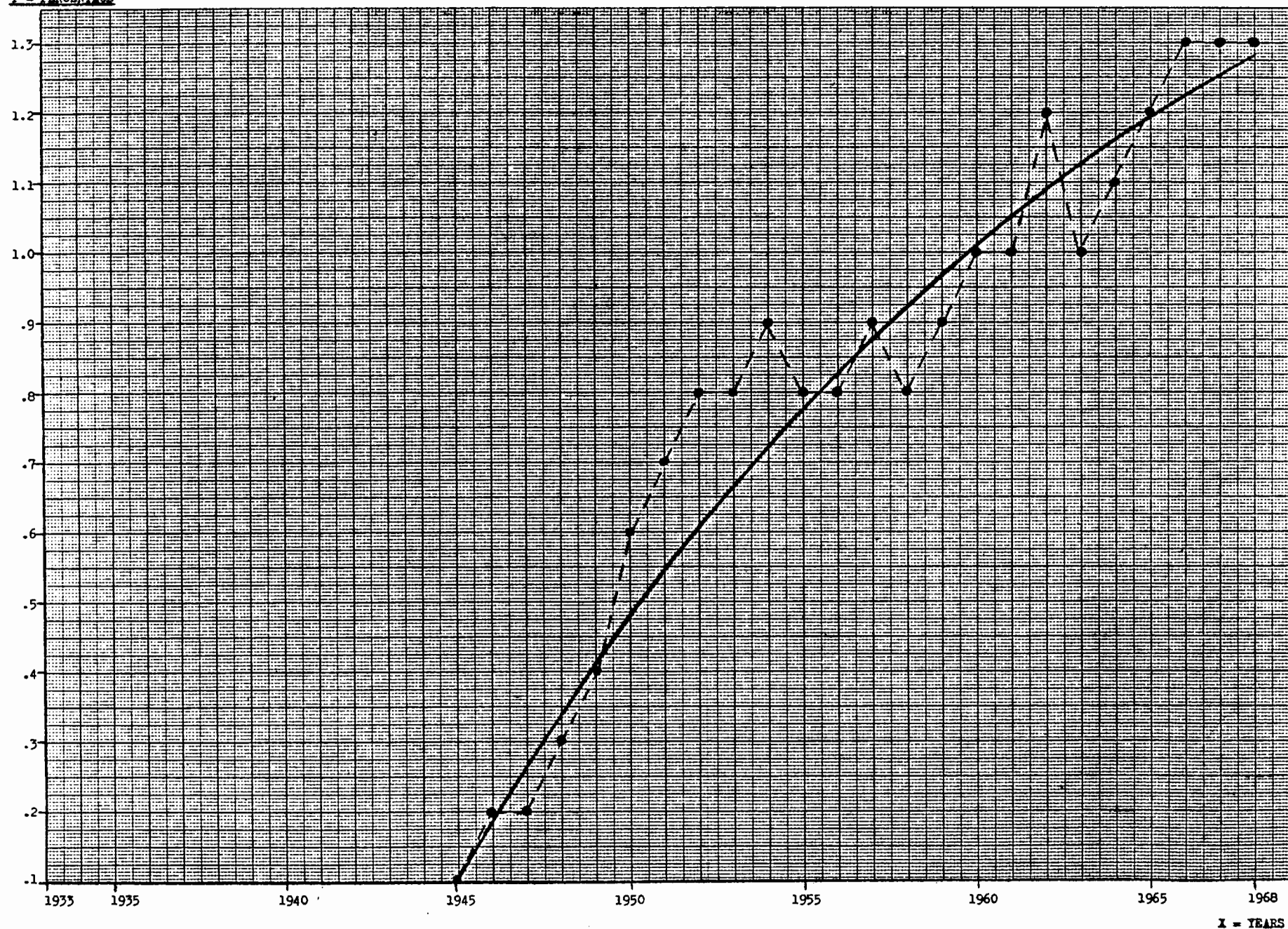


FIGURE 33: MARKET SHARE OF OIL IN MINING, 1945 - 1968

$$\bar{Y} = 1.885 - 1.785 (0.9537)^{X-1945}$$

Y = PERCENTAGE



Lastly, the following equation applied to oil:

$$Y = 1.885 - 1.785(0.9537)^{X-1945}$$

where Y = market share of oil

X = year

Forecast market shares were again obtained by extrapolating these relationships. The results, so obtained, were marginally different from 100 per cent and differences were prorated over the two major forms of energy. The final results appear in Table 58, the sectoral energy forecast being obtained from Table 51.

5.3.2.4 Transport sector

Market shares of the three forms of energy in the transport sector, as given in Table 44, are depicted in Figures 34, 35 and 36.

For electricity, the following modified exponential was considered appropriate from 1957 onwards:

$$Y = 11.85 - 5.1226(0.85704)^{X-1957}$$

where Y = market share of electricity

X = year

In the case of coal, a Gompertz curve was fitted, as indicated, and assumed the form:

$$Y = (34.834)(0.93508)^{(1.1694)^{X-1951}}$$

where Y = market share of coal

X = year

TABLE 58: FORECAST DEMAND PATTERN OF ENERGY IN MINING SECTOR, 1968 TO 2000

(10⁶ MEGAJOULES)

	1968		1980		1990		2000	
	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ELECTRICITY	34,546	66.9	48,463	71.0	65,513	72.9	88,207	73.8
COAL	16,400	31.8	18,498	27.1	22,646	25.2	29,044	24.3
OIL	703	1.3	1,297	1.9	1,707	1.9	2,271	1.9
COAL GAS								
OTHER GAS								
COKE								
GAS COKE								
TOTAL	51,649	100.0	68,258	100.0	89,866	100.0	119,522	100.0

FIGURE 35: MARKET SHARE OF COAL IN TRANSPORT, 1933 - 1968

$$\bar{Y} = (34.834)(0.93508)^{(X-1951)}$$

Y = PERCENTAGE

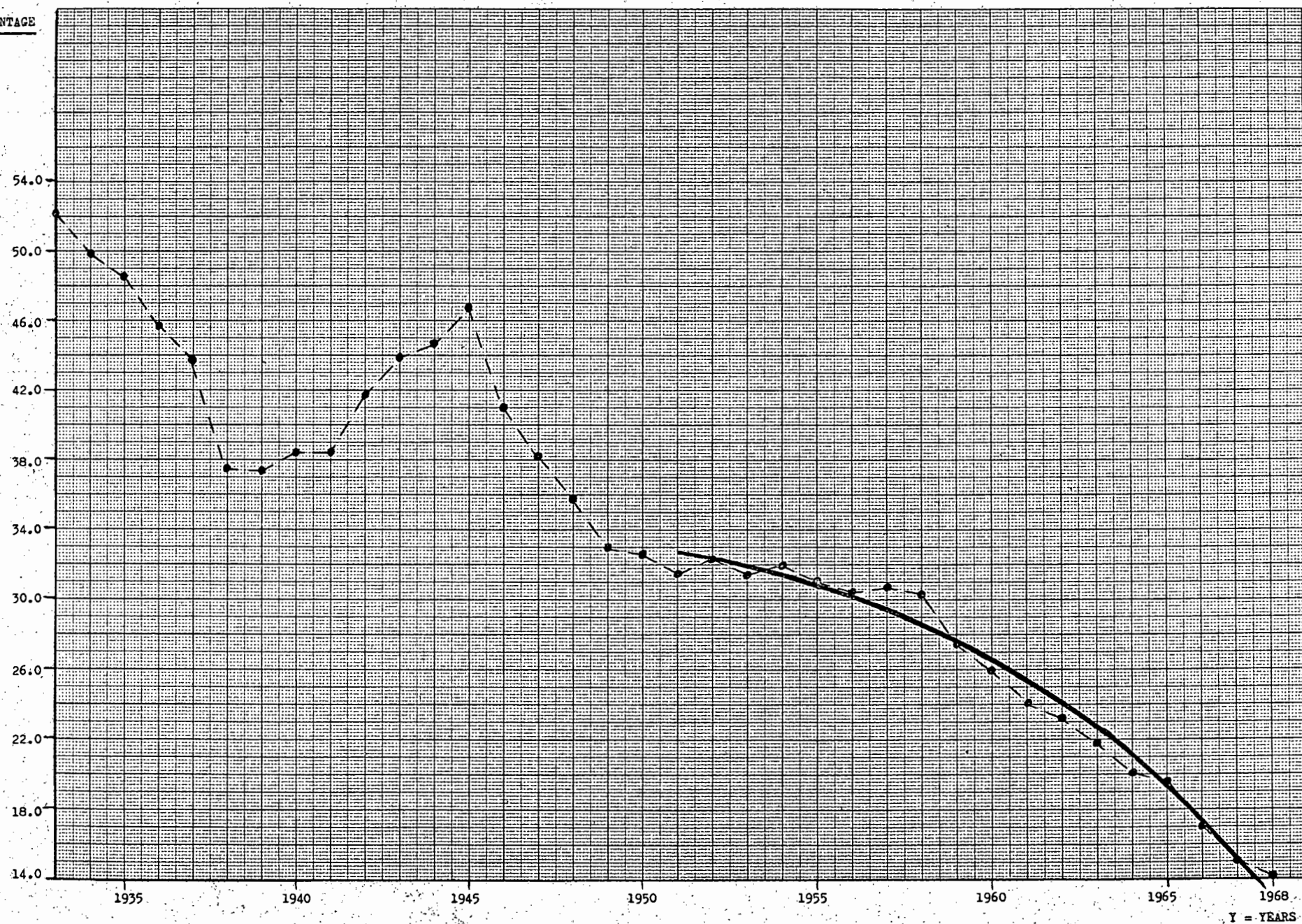
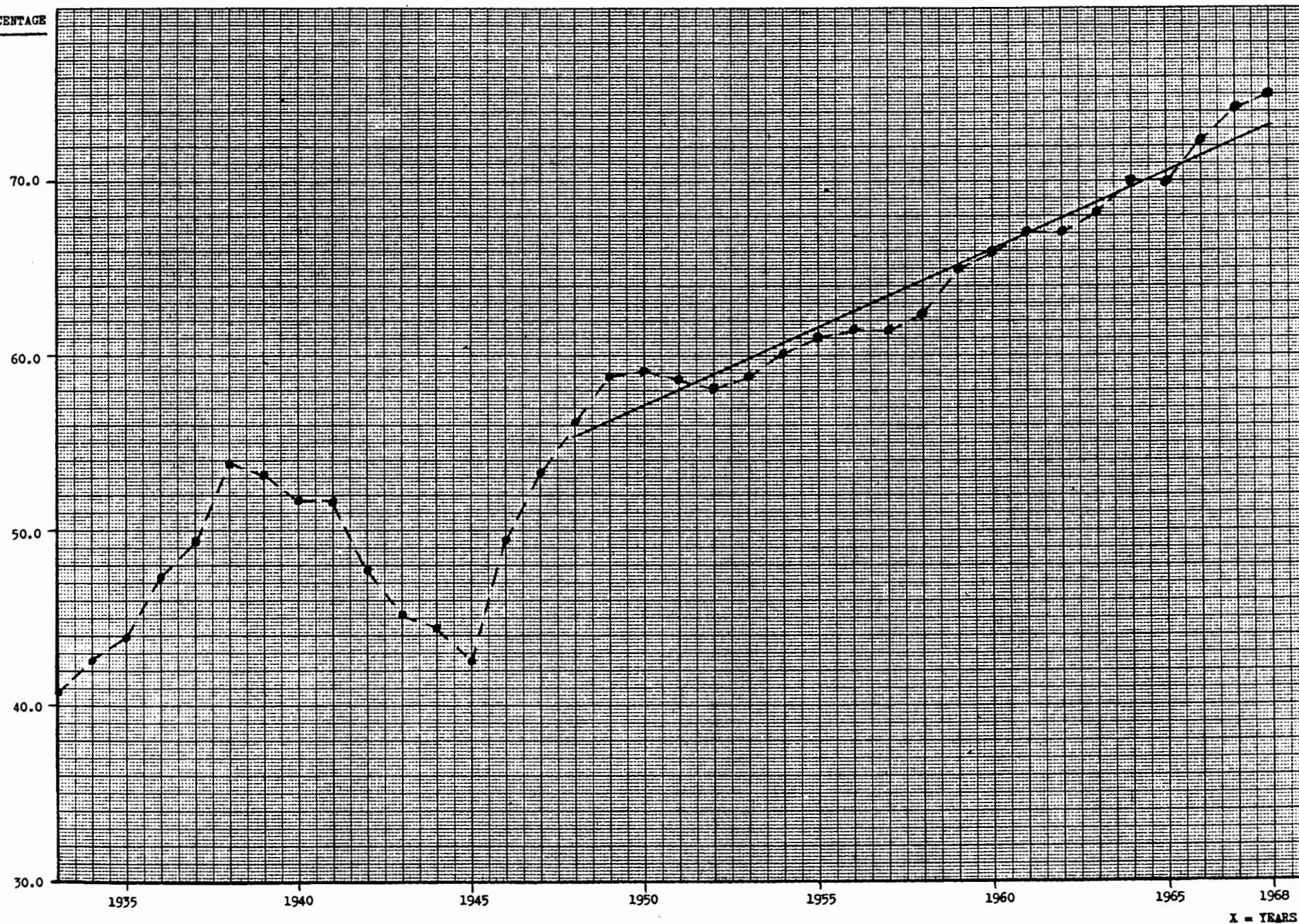


FIGURE 36: MARKET SHARE OF OIL IN TRANSPORT, 1933 - 1968

$$\bar{Y} = -1686.2 + 0.894X$$

Y = PERCENTAGE



Lastly, the following straight line appeared best to fit the trend for oil:

$$Y = -1686.2 + 0.894X$$

where Y = market share of oil

X = year

It was again found that extrapolations of the above relationships yielded unrealistic results and have therefore been rejected. It was eventually found that the market holdings of the three forms of energy could be rationalised satisfactorily on other grounds. As each of the three forms of energy satisfies the demand of a distinct mode of transport, the approach centred on forecasting their future volumes, rather than their respective market shares.

Coal consumed in the transport sector is of course only used by the South African Railways in their steam-driven locomotives. Discussion with officials of the Administration indicated that it is their policy not to buy any further steam engines.¹⁹⁷ At the same time, the objective is to have all main lines electrified by 1985. This does not, however, mean that steam engines will be scrapped. When no longer suitable for main line service, but still in working condition, these engines are useful for shunting purposes. The official estimate of the Administration is that their coal consumption, for this purpose, will decline by about 300,000 tons a year. As the useful lives of steam engines are of considerable length, they have therefore not been phased out altogether. Figures appearing in Table 59 therefore represent the future consumption of coal by the steam-driven engines of the Railways. Corresponding market shares have been calculated by using the transport energy forecast as given in Table 53.

TABLE 59: FORECAST DEMAND PATTERN OF ENERGY IN TRANSPORT SECTOR, 1968 TO 2000

(10⁶ MEGAJOULES)

	1968		1980		1990		2000	
	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ELECTRICITY	5,962	10.8	13,795	13.3	22,956	13.2	36,948	12.9
COAL	7,830	14.2	5,455	5.2	3,999	2.3	2,577	0.9
OIL	41,330	75.0	85,398	81.5	146,955	84.5	246,892	86.2
COAL GAS								
OTHER GAS								
COKE								
GAS COKE								
TOTAL	55,122	100.0	104,648	100.0	173,910	100.0	286,417	100.0

With the declining role of the steam engine it is only logical to expect that the bulk of the rail transport demands of the future will have to be met by the electric locomotive. Diesel traction is relatively insignificant at present, and is expected to remain so in future. It is the policy of the Administration to use diesels only for shunting in urban areas, to help combat atmospheric pollution, or to use them in the rural parts of the country where water is scarce.

Electricity consumed in the transport sector (column (1), Table 39) was therefore correlated with railway ton-miles (column (9), Table 46). Fig. 37 indicates the nature of the scatter obtained. The following straight line was fitted for the period 1955 to 1968, the calculated coefficient of correlation being 0.992:

$$Y = -2462.7 + 0.22556X$$

where Y = electricity in transport
 X = railway ton-miles

By using the forecast of railway ton-miles, as given in column (2) of Table 53, a forecast of electricity consumption in the transport sector can be made.

The forecast of railway ton-miles referred to was obtained from a study^{110/} of the Transport Research Centre. As a control, it was decided to correlate railway ton-miles with real gross domestic product, as indicated in Fig. 38. A remarkably close relationship resulted. The calculated correlation coefficient was 0.997, with resulting equation:

$$Y = 52.19 + 4.6152X$$

where Y = railway ton-miles
 X = real gross domestic product

FIGURE 37: ELECTRICITY IN TRANSPORT VERSUS RAILWAY TON-MILES, 1955 - 1968

$$\hat{Y} = -2462.7 + 0.22556X$$

Y = TRANS
PORT
ELECTRIC-
ITY
(10⁶ MEGA-
JOULES)

5,000

3,000

1,000

5,000

15,000

25,000

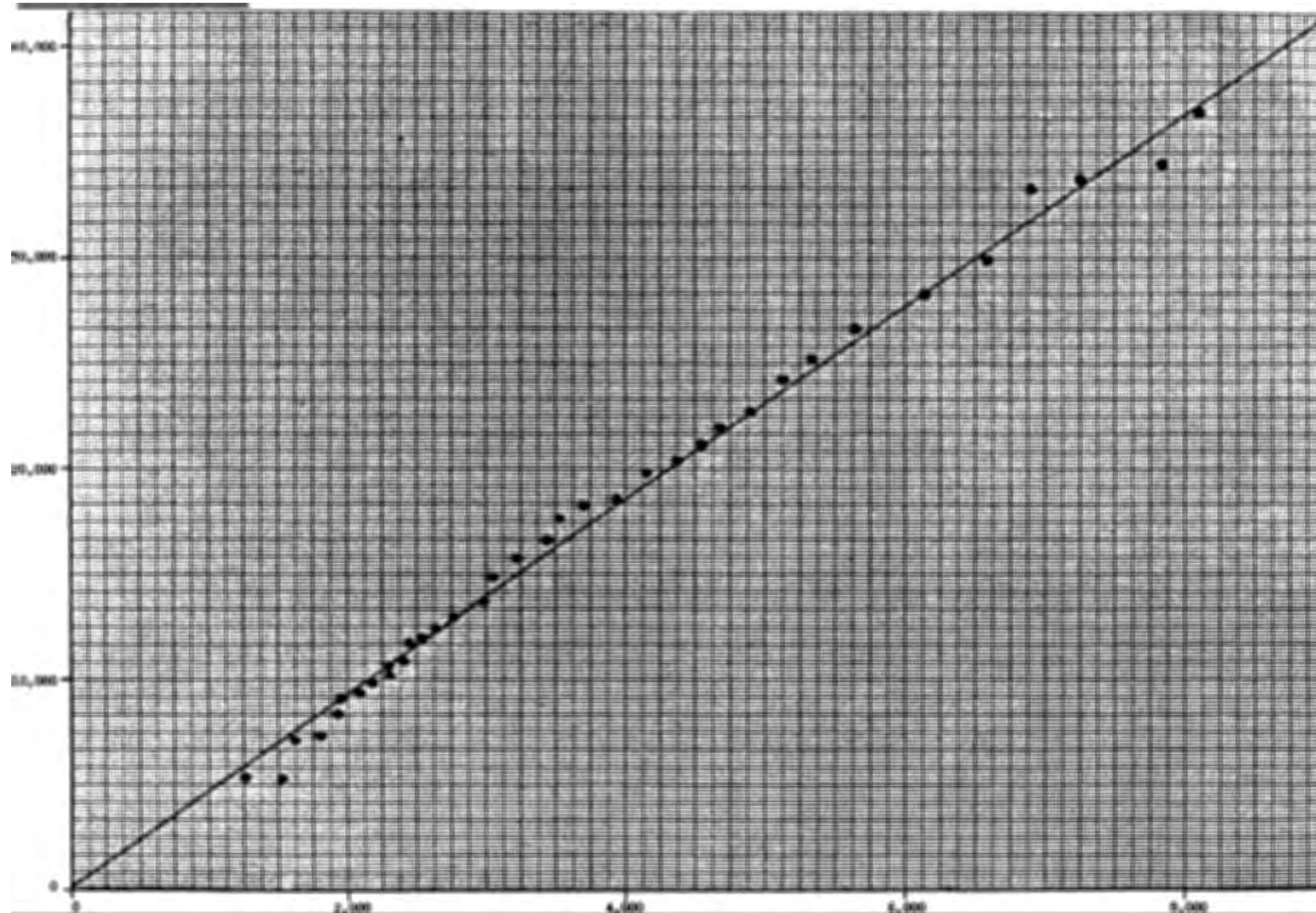
35,000

X = RAILWAY TON-MILES
(MILLIONS)

FIGURE 38: RAILWAY TON-MILES VERSUS REAL GROSS DOMESTIC PRODUCT, 1933 - 1968

$$\hat{Y} = 52.19 + 4.6152X$$

Y = RAILWAY TON-MILES (MILLIONS)



X = REAL G.D.P.
(R MILLION)

The control forecast of electricity consumption in the transport sector, thus derived, was found to be very close to the alternative.

As virtually all oil consumed in the transport sector is used by motor vehicles for road transport, it was decided to make a regression analysis between oil consumed in the transport sector (column (3), Table 39) and the motor vehicle population (column (3), Table 34). The scatter diagram is presented in Fig. 39. The relationship which was calculated over the period 1947 to 1968, yielded a correlation coefficient of 0.9989 with resulting equation:

$$Y = 504.2 + 22.17X$$

where Y = oil in transport

X = motor vehicle population

By using the forecast of motor vehicles, as given in Table 52, a forecast of the oil demand in the transport sector can now be made.

In this way, volume forecasts were derived for all three sources of energy in the transport sector. The aggregates of these forecasts, for successive years, were found to be marginally different from the sectoral totals as given in Table 59. Differences were again eliminated by proration and the future market shares of each source of energy calculated, as indicated in Table 59.

5.3.2.5 Total all sectors

In Table 60, the sectoral demand patterns, rationalised in the previous section, are consolidated and the contributions of the various energy-producing agents established over all sectors.

FIGURE 39: OIL IN TRANSPORT VERSUS MOTOR VEHICLE POPULATION, 1947 - 1968

$$\bar{Y} = 504.2 + 22.17X$$

Y = OIL
IN TRANS-
PORT.
(10⁶ MEGA-
JOULES)

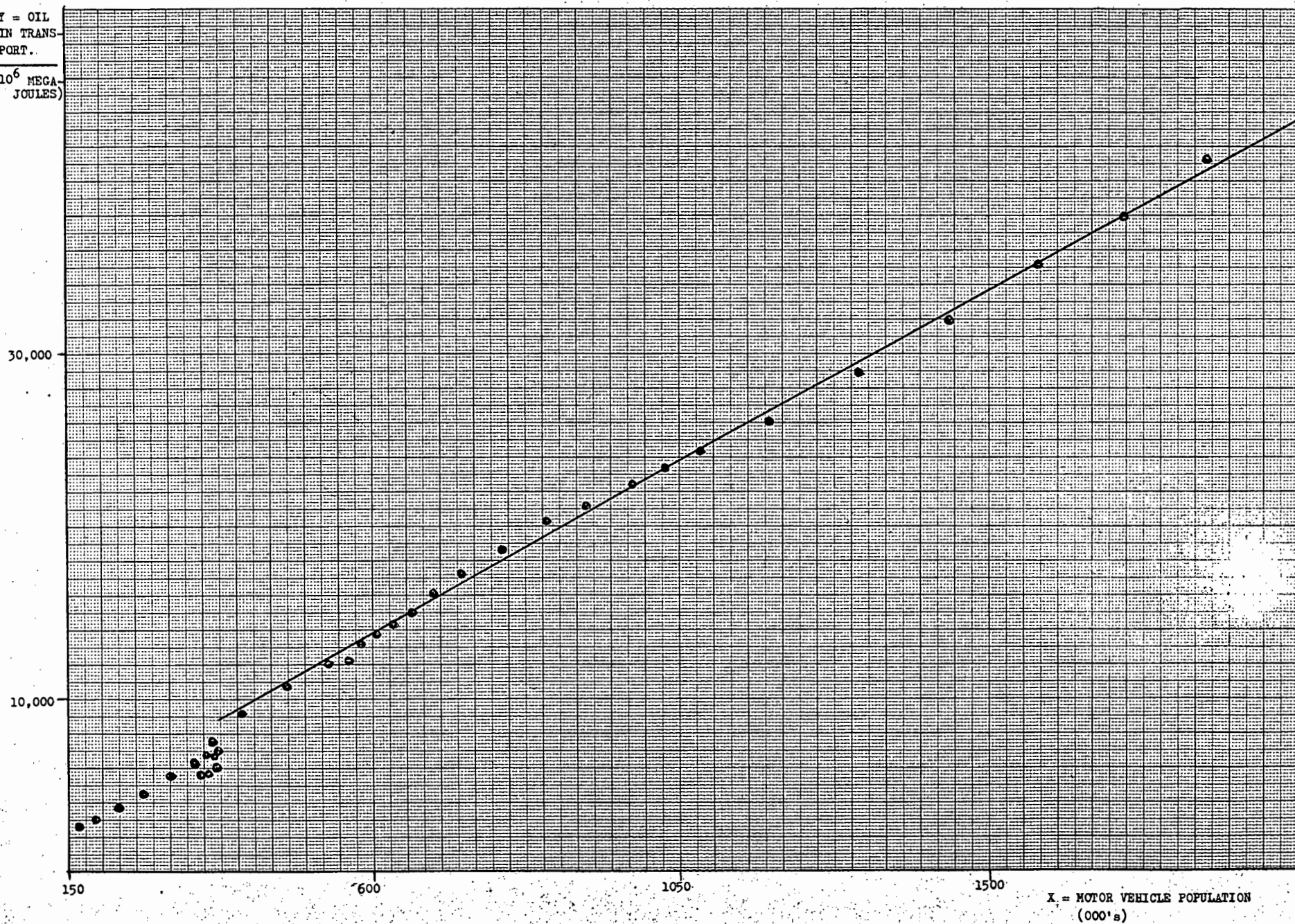


TABLE 60: FORECAST ENERGY DEMAND PATTERN ALL SECTORS, 1968 TO 2000

(10⁶ MEGAJOULES)

	HOUSEHOLDS		INDUSTRY		MINING		TRANSPORT		TOTAL	
1968	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE	VOLUME	PERCENTAGE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ELECTRICITY	17,464	32.6	41,063	17.9	34,546	66.9	5,962	10.8	99,035	25.4
COAL	16,960	31.7	65,660	28.6	16,400	31.8	7,830	14.2	106,850	27.4
OIL	18,500	34.6	14,492	6.3	703	1.3	41,330	75.0	75,025	19.3
COAL GAS	474	0.9	2,255	1.0	-	-	-	-	2,729	0.7
OTHER GAS	-	-	32,038	14.0	-	-	-	-	32,038	8.2
COKE	-	-	73,079	31.9	-	-	-	-	73,079	18.8
GAS COKE	118	0.2	580	0.3	-	-	-	-	698	0.2
TOTAL	53,516	100.0	229,167	100.0	51,649	100.0	55,122	100.0	389,454	100.0
1980										
ELECTRICITY	41,958	40.8	112,086	22.7	48,463	71.0	13,795	13.3	216,302	28.1
COAL	19,258	18.7	64,954	13.2	18,498	27.1	5,455	5.2	108,165	14.1
OIL	41,193	40.0	93,106	18.8	1,297	1.9	85,398	81.5	220,994	28.7
COAL GAS	456	0.4	4,938	1.0	-	-	-	-	5,394	0.7
OTHER GAS	-	-	72,090	14.6	-	-	-	-	72,090	9.3
COKE	-	-	146,156	29.6	-	-	-	-	146,156	19.0
GAS COKE	118	0.1	440	0.1	-	-	-	-	558	0.1
TOTAL	102,983	100.0	493,770	100.0	68,258	100.0	104,648	100.0	769,659	100.0
1990										
ELECTRICITY	80,174	47.2	248,929	27.2	65,513	72.9	22,956	13.2	417,572	31.0
COAL	18,321	10.8	90,830	9.9	22,646	25.2	3,999	2.3	135,796	10.1
OIL	70,570	41.6	154,914	16.9	1,707	1.9	146,955	84.5	374,146	27.7
COAL GAS	456	0.3	9,152	1.0	-	-	-	-	9,608	0.7
OTHER GAS	-	-	142,768	15.6	-	-	-	-	142,768	10.6
COKE	-	-	268,148	29.3	-	-	-	-	268,148	19.9
GAS COKE	118	0.1	440	0.1	-	-	-	-	558	0.0
TOTAL	169,639	100.0	915,181	100.0	89,866	100.0	173,910	100.0	1,348,596	100.0
2000										
ELECTRICITY	147,425	52.6	507,136	31.8	88,207	73.8	36,948	12.9	779,716	34.2
COAL	15,136	5.4	129,241	8.1	29,044	24.3	2,577	0.9	175,998	7.7
OIL	117,166	41.8	216,383	13.6	2,271	1.9	246,892	86.2	582,712	25.6
COAL GAS	456	0.2	15,948	1.0	-	-	-	-	16,404	0.7
OTHER GAS	-	-	263,137	16.5	-	-	-	-	263,137	11.5
COKE	-	-	462,482	29.0	-	-	-	-	462,482	20.3
GAS COKE	118	0.0	440	0.0	-	-	-	-	558	0.0
TOTAL	280,301	100.0	1,594,767	100.0	119,522	100.0	286,417	100.0	2,281,007	100.0

Table 60 shows that the share of electricity in the final consumption sector is expected to grow from 25.4 per cent in 1968, to 28.1 per cent in 1980, 31.0 per cent in 1990 and 34.2 per cent in the year 2000. The market share of coal is expected to drop rapidly, the severest drop occurring in the next decade, owing to developments outlined in the industrial sector. Oil's share shows corresponding rapid increases over the next decade, but declines marginally thereafter. The steadily increasing market shares of other gas and coke are in accordance with rapid growth anticipated in the metallurgical sector of the economy.

It is, of course, very interesting to observe trends in market shares of the various sources of energy in total, over all sectors. This may, with qualification, serve possibly as a control on the aggregate of energy source market shares for individual sectors, as established above.

Graphs have, therefore, also been drawn of the data appearing in Table 45, as shown in Figures 40 to 46. Relationships considered appropriate to the historical period under review, or parts of it, have again been fitted to the observations, as indicated in the graphs.

For electricity, a straight line was used, as indicated in Fig. 40, with resulting equation:

$$Y = -864.1 + 0.452X$$

where Y = total market share of electricity

X = year

The progression of market shares for coal (Fig. 41) corresponded to the following straight line:

FIGURE 40: MARKET SHARE OF ELECTRICITY IN TOTAL, 1933 - 1968

$$\hat{Y} = -864.1 + 0.452X$$

Y = PERCENTAGE

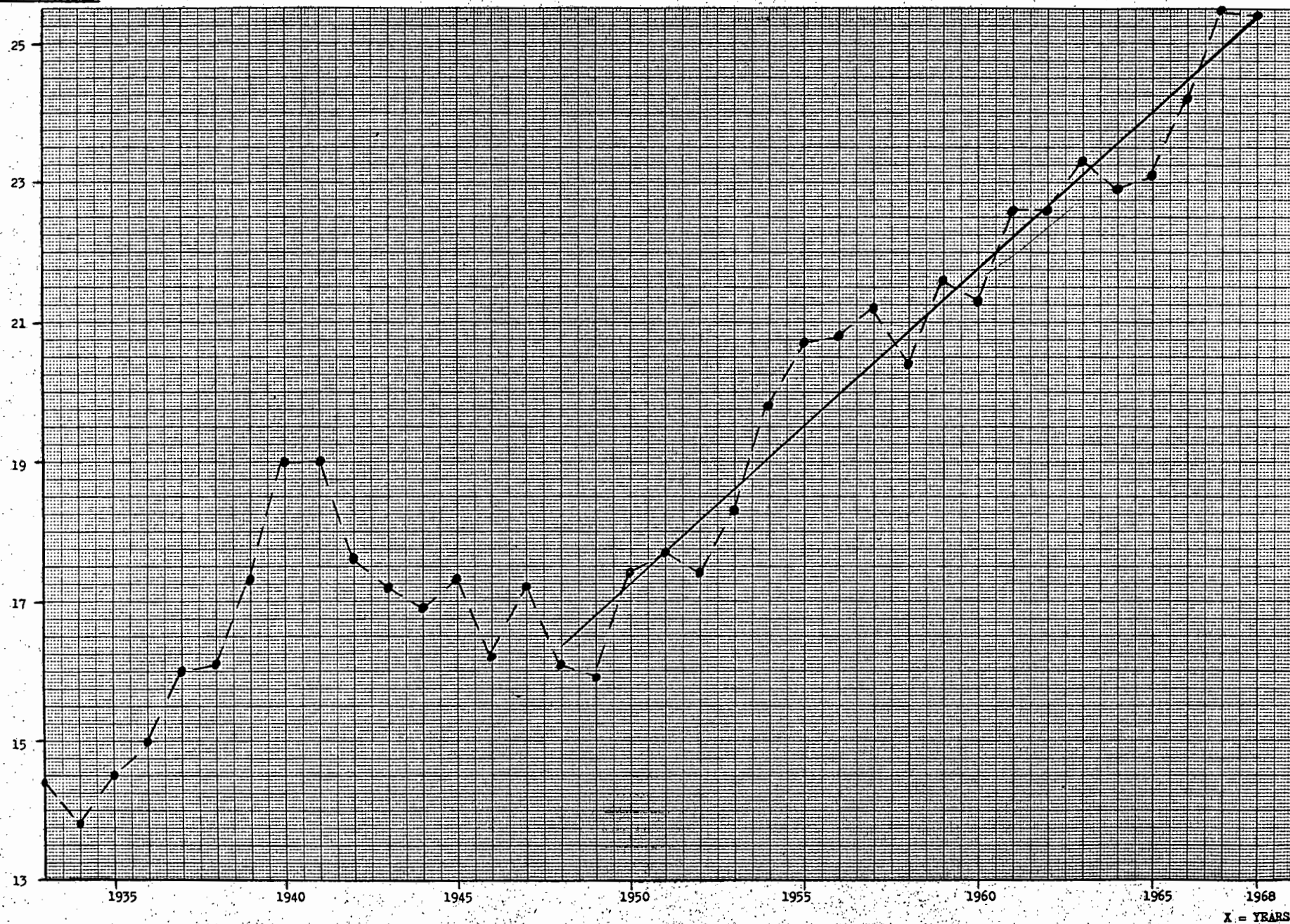


FIGURE 41: MARKET SHARE OF COAL IN TOTAL, 1933 - 1968

$$\bar{Y} = 2096.5 - 1.05x$$

Y = PER-
CENTAGE

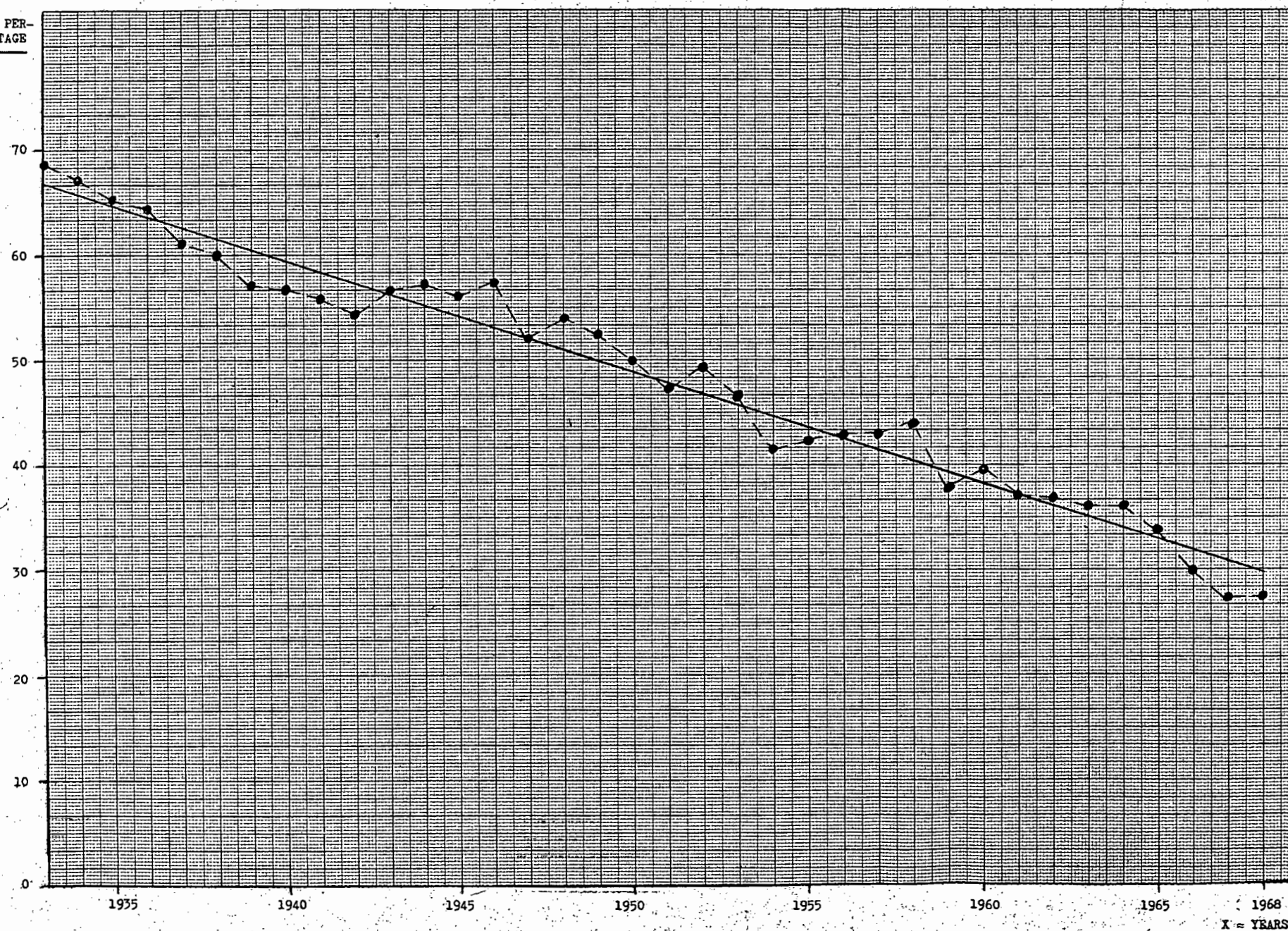


FIGURE 42: MARKET SHARE OF OIL IN TOTAL, 1953 - 1968

$$\hat{Y} = -602.1 + 0.315X$$

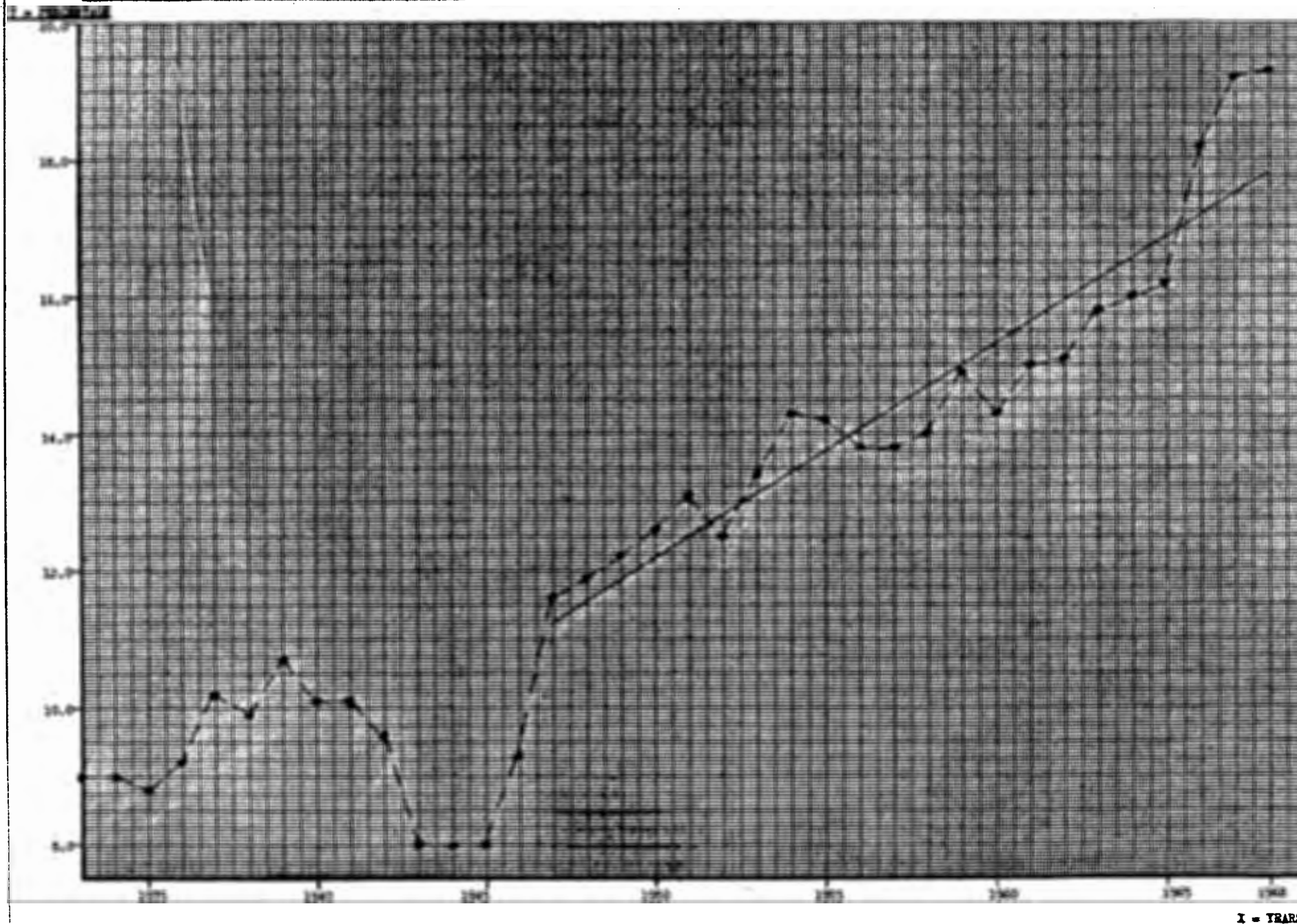
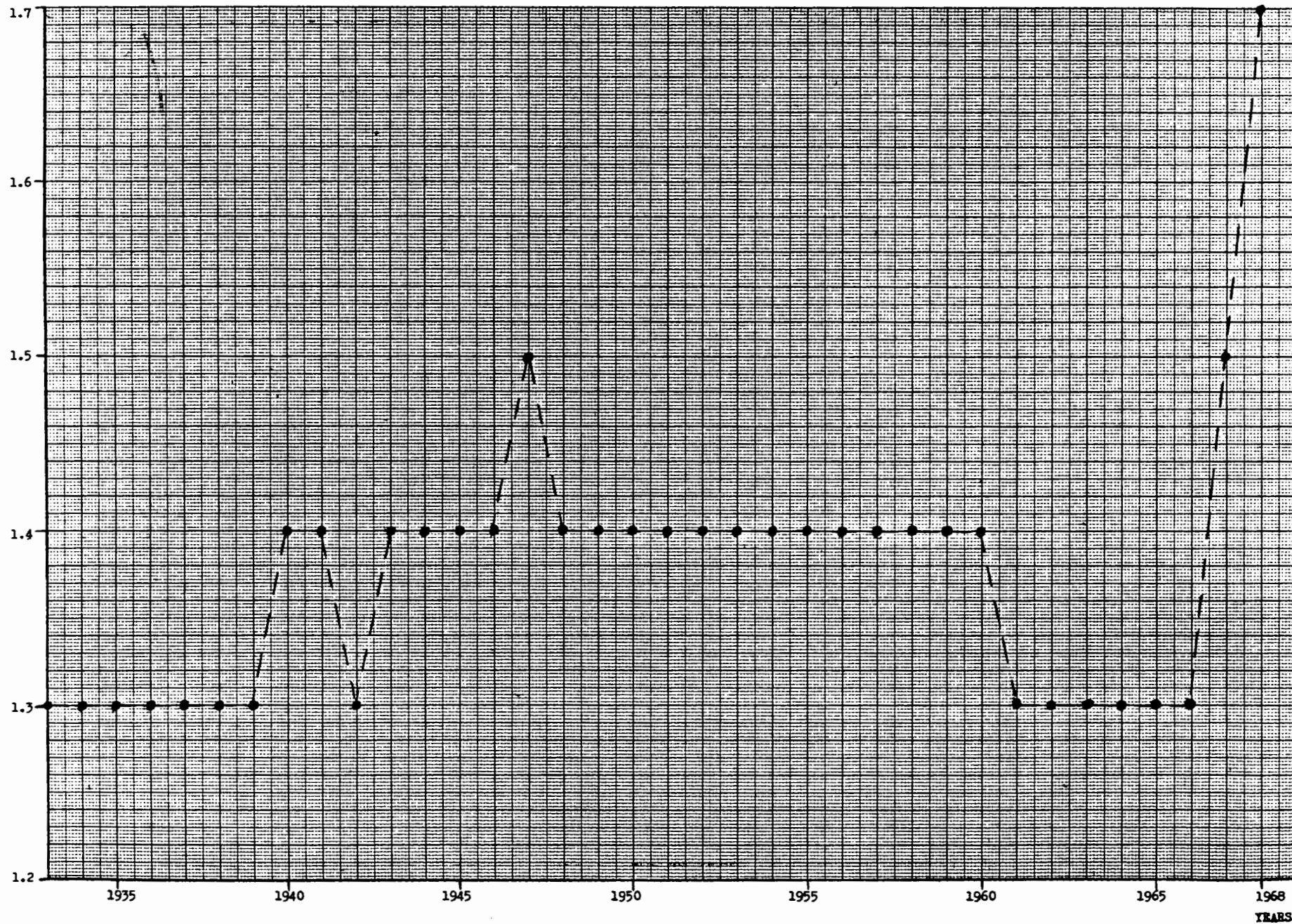


FIGURE 43: MARKET SHARE OF COAL GAS, 1933 - 1968

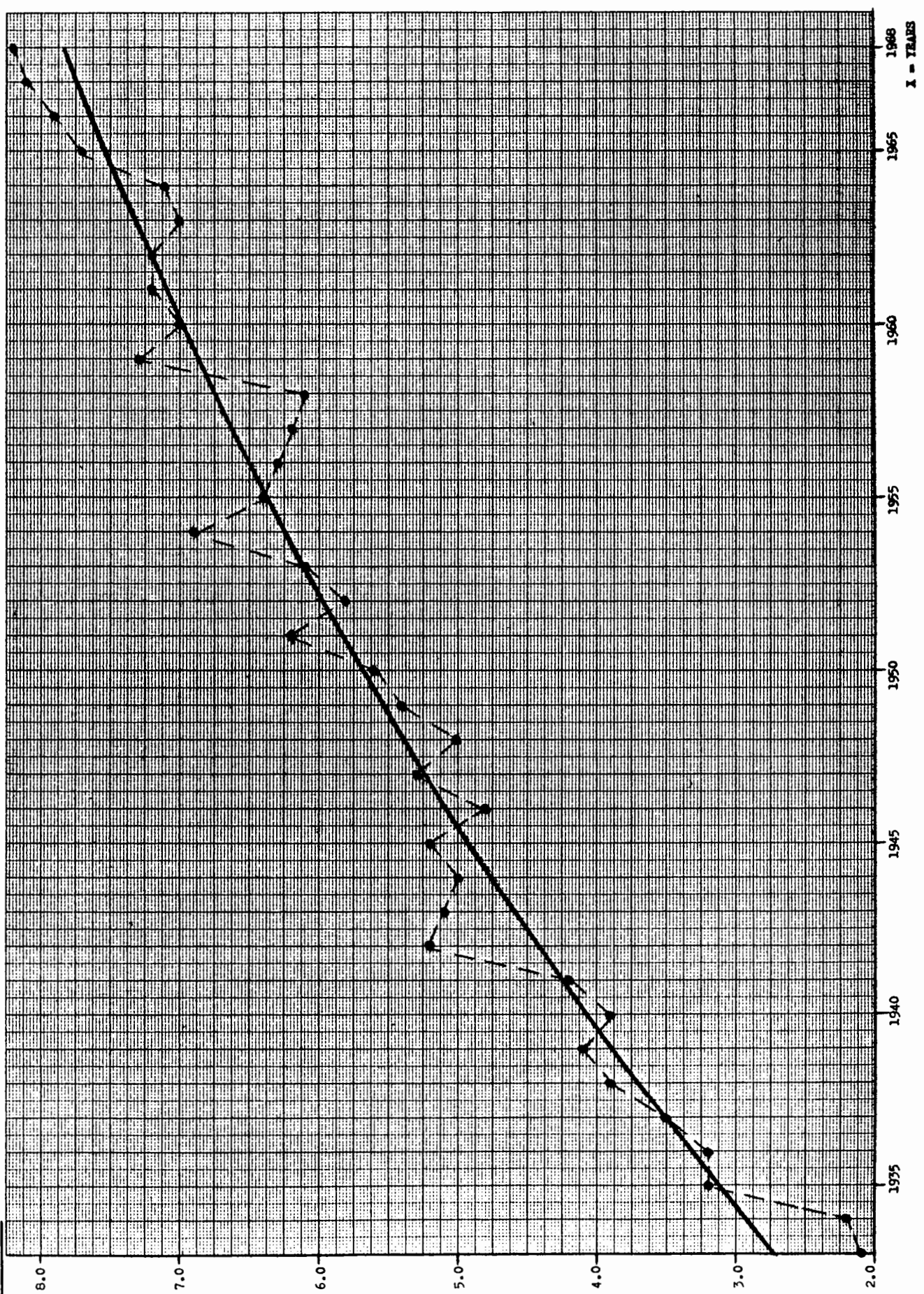
PERCENTAGE



$\bar{R} = 12.275 - 9.565 (0.97857)^{X-1933}$

FIGURE 44: MARKET SHARE OF OTHER GAS IN TOTAL, 1933 - 1968

Y = PERCENTAGE



X = YEARS

FIGURE 45: MARKET SHARE OF COKE IN TOTAL, 1933 - 1968

$$\hat{Y} = 29.47 - 22.575 (0.97836)^{X-1933}$$

Y = PER-
CENTAGE

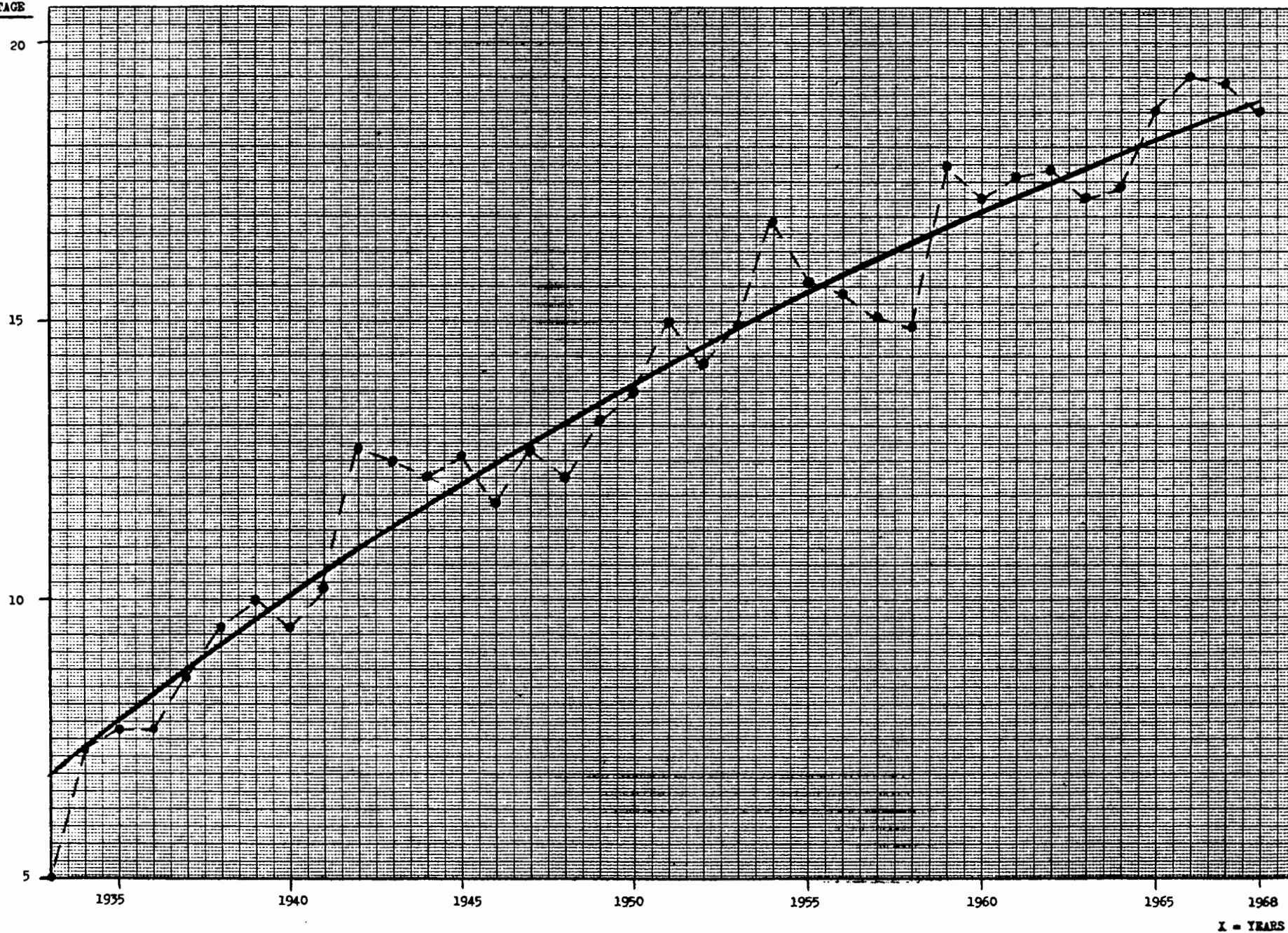
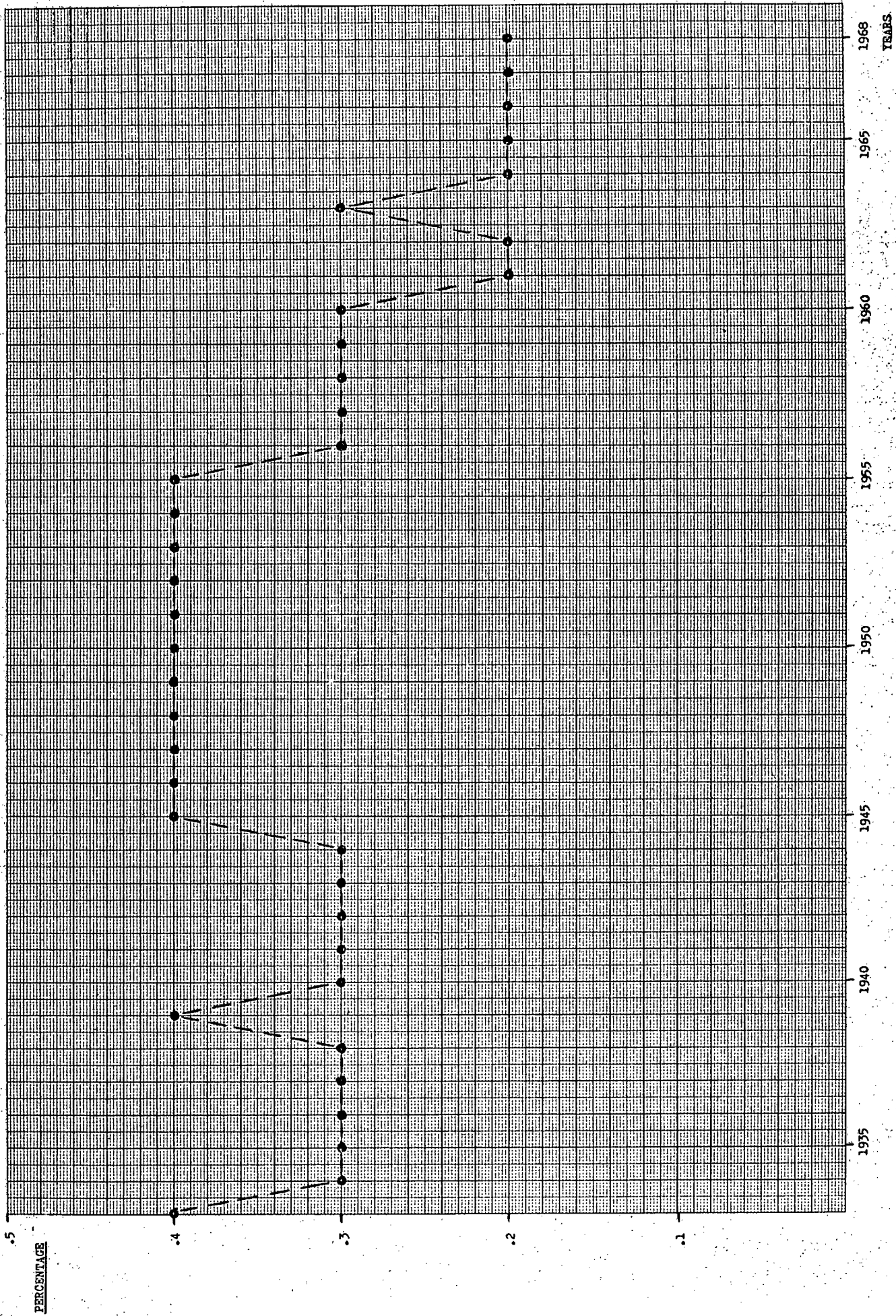


FIGURE 46: MARKET SHARE OF GAS COKE, 1933 - 1968



$$Y = 2096.5 - 1.05X$$

where Y = total market share of coal

X = year

A linear relationship was fitted to the market shares of oil (Fig.42) for the period after 1947 with equation:

$$Y = -602.1 + 0.315X$$

where Y = total market share of oil

X = year

As indicated in Fig. 44, the following modified exponential appeared best to fit the observations for other gas:

$$Y = 12.275 - 9.565 (0.97837)^{X-1933}$$

where Y = total market share of other gas

X = year

Lastly, a modified exponential was also fitted to the historical values for coke (Fig. 45), yielding the following relationship:

$$Y = 29.47 - 22.575 (0.97836)^{X-1933}$$

where Y = total market share of coke

X = year

Observations in respect of the two remaining forms of energy, i.e. coal gas and gas coke (Figures 43 and 46) again did not correspond to a reasonable pattern and no relationships were therefore considered for them.

Extrapolations made from these relationships are summarised in Table 61. Projected market shares for coal gas and gas coke were taken from Table 60, in order to obtain an indication of the total of

TABLE 61: CONTROL FORECAST, EXTRAPOLATION OF TOTAL MARKET SHARES OF

FORMS OF ENERGY, 1968 TO 2000

(PERCENTAGES)

	1968	1980	1990	2000
ELECTRICITY	25.4	30.8	35.3	39.9
COAL	27.4	17.4	7.0	-
OIL	19.3	21.6	24.8	27.9
COAL GAS	0.7	0.7	0.7	0.7
OTHER GAS	8.2	8.9	9.6	9.7
COKE	18.8	21.4	23.0	24.3
GAS COKE	0.2	0.1	0.0	0.0
TOTAL	100.0	100.9	100.4	102.5

all market shares, as outlined in Table 61.

It will be observed, by comparing the results obtained in Table 61 with comparable figures in Table 60, that there is a fair degree of correspondence between the two sets of aggregate market shares, except for coal, where a more detailed analysis was obviously required.

Finally, it is important to consider developments in the relative contributions of the final consumption sectors to total demand for energy. Table 62 provides the historical sectoral distribution of energy demand and gives an indication of what may be expected in the future, by looking at the forecasts as provided in Table 60.

TABLE 62: SECTORAL DISTRIBUTION OF TOTAL ENERGY DEMAND, 1935 TO 2000

(PERCENTAGES)

YEAR	HOUSEHOLDS	INDUSTRY	MINING	TRANSPORT	TOTAL
	(1)	(2)	(3)	(4)	(5)
1935	17.9	24.5	44.7	12.9	100.0
1940	16.5	30.0	39.5	14.0	100.0
1945	15.8	41.3	32.0	10.9	100.0
1950	16.6	47.0	23.5	12.9	100.0
1955	17.0	51.3	18.4	13.3	100.0
1960	15.0	56.4	15.6	13.0	100.0
1965	14.3	59.1	13.5	13.1	100.0
1968	13.7	58.8	13.3	14.2	100.0
1980	13.4	64.1	8.9	13.6	100.0
1990	12.5	67.9	6.7	12.9	100.0
2000	12.3	69.9	5.2	12.6	100.0

The observations speak for themselves. During the next 30 years, the industrial sector, already the biggest, will continue to increase its share of the total, completely dominating the South African energy economy by the turn of the century. By contrast, the share of the mining sector, a one-time giant, will be reduced to the smallest component of total energy demand, by 2000.

5.3.3 Control forecasts

It has been possible to establish a few independent checks or controls on the forecasts detailed in Table 60. As will be seen, in some cases the technique of extrapolating on the basis of observed past relationships was again applied, and, in others, forecasts were based on homologous trends in other countries of the world. In this instance, control forecasts can only be offered for the households and industrial sectors, and the total.

5.3.3.1 Electricity

In the households sector, electricity consumption was related to real gross domestic product, as shown in Fig. 47. A straight line appeared to fit the observations best. The calculated correlation coefficient equalled 0.994 and the following equation was obtained:

$$Y = -3224.5 + 2.5614X$$

where Y = electricity consumption in households

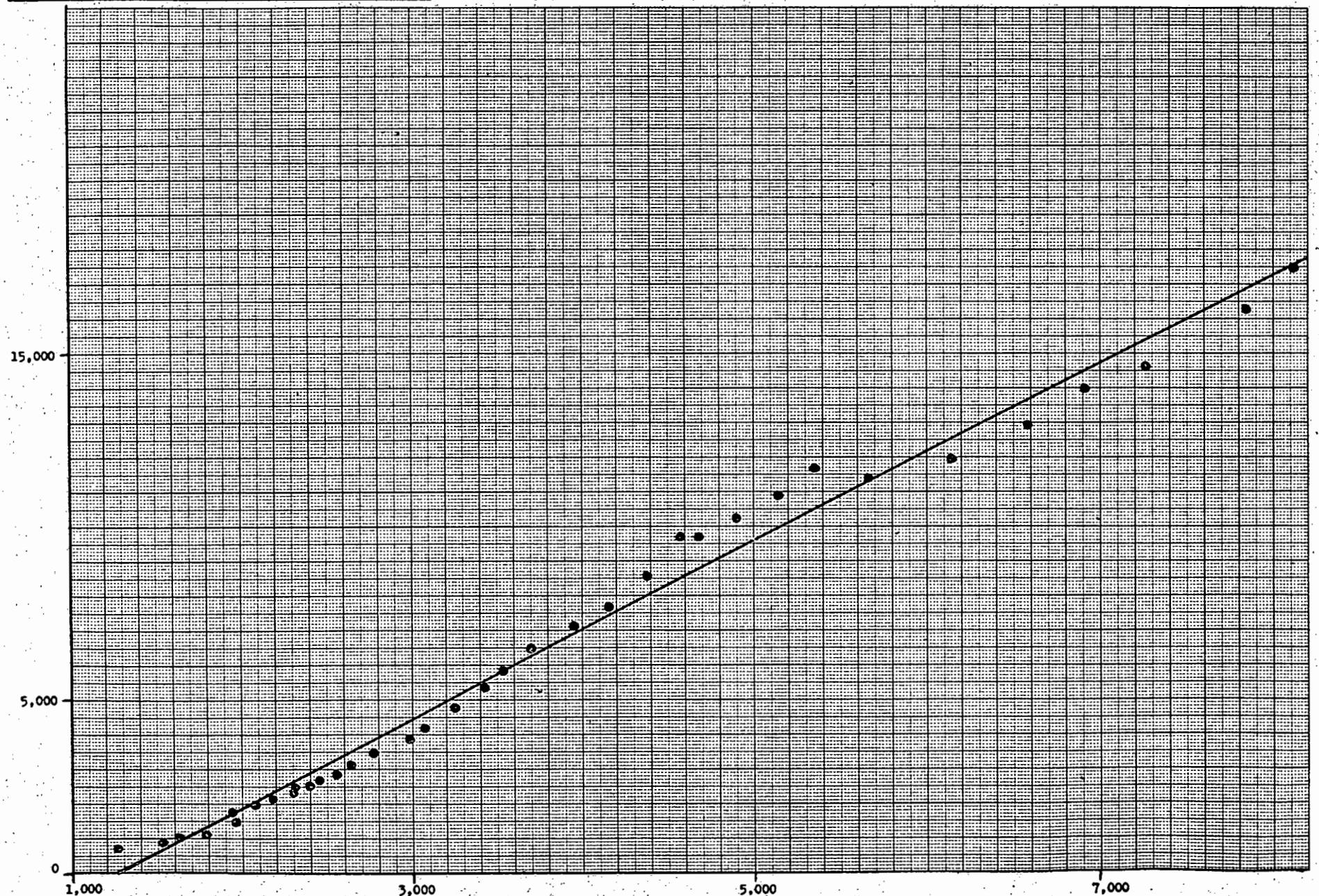
X = real G.D.P.

The resultant control forecast for electricity consumption in the households sector is indicated in column (1) of Table 63.

FIGURE 47: HOUSEHOLDS ELECTRICITY VERSUS REAL GROSS DOMESTIC PRODUCT, 1933 - 1968

$$\hat{Y} = -3224.5 + 2.5614X$$

Y = ELECTRICITY CONSUMPTION BY HOUSEHOLDS (10^6 MEGAJOULES)



X = REAL G.D.P.
(R MILLION)

TABLE 63: CONTROL FORECASTS OF ENERGY DEMAND, 1980, 1990 AND 2000

(10⁶ MEGAJOULES)

	HOUSEHOLDS	INDUSTRY	MINING	TRANSPORT	TOTAL
1980	(1)	(2)	(3)	(4)	(5)
ELECTRICITY	36,269	99,582			217,032
COAL					
OIL	40,077				160,973
COAL GAS					
OTHER GAS					
COKE		149,488			149,488
GAS COKE					
TOTAL					695,323
1990					
ELECTRICITY	64,234	207,930			403,780
COAL					
OIL	70,206				286,641
COAL GAS					
OTHER GAS					
COKE		262,546			262,546
GAS COKE					
TOTAL					1,088,588
2000					
ELECTRICITY	112,004	373,344			758,088
COAL					
OIL	121,672				495,275
COAL GAS					
OTHER GAS					
COKE		455,681			455,681
GAS COKE					
TOTAL					1,638,137

In the industrial sector, electricity consumption was correlated with real value of gross manufacturing output, as presented in Figure 48. The observations for the period after 1951 corresponded to a straight line, as shown in the diagram. The regression yielded a correlation coefficient of 0.988 and the following equation resulted:

$$Y = -11857.5 + 10.5471X$$

where Y = electricity consumption in industry
 X = real manufacturing output.

The forecasts are given in the second column of Table 63.

A global forecast of total electricity made by Straszacker⁵⁵⁷ is also included for control purposes. Straszacker adapted the comparative approach, first expounded by Felix, for South African conditions, and made a forecast of electricity generation up to the turn of the century. The control forecast included in column (5) of Table 63 was made on the assumption that consumption of electricity will grow at the same rate as the production forecast, made by Straszacker.

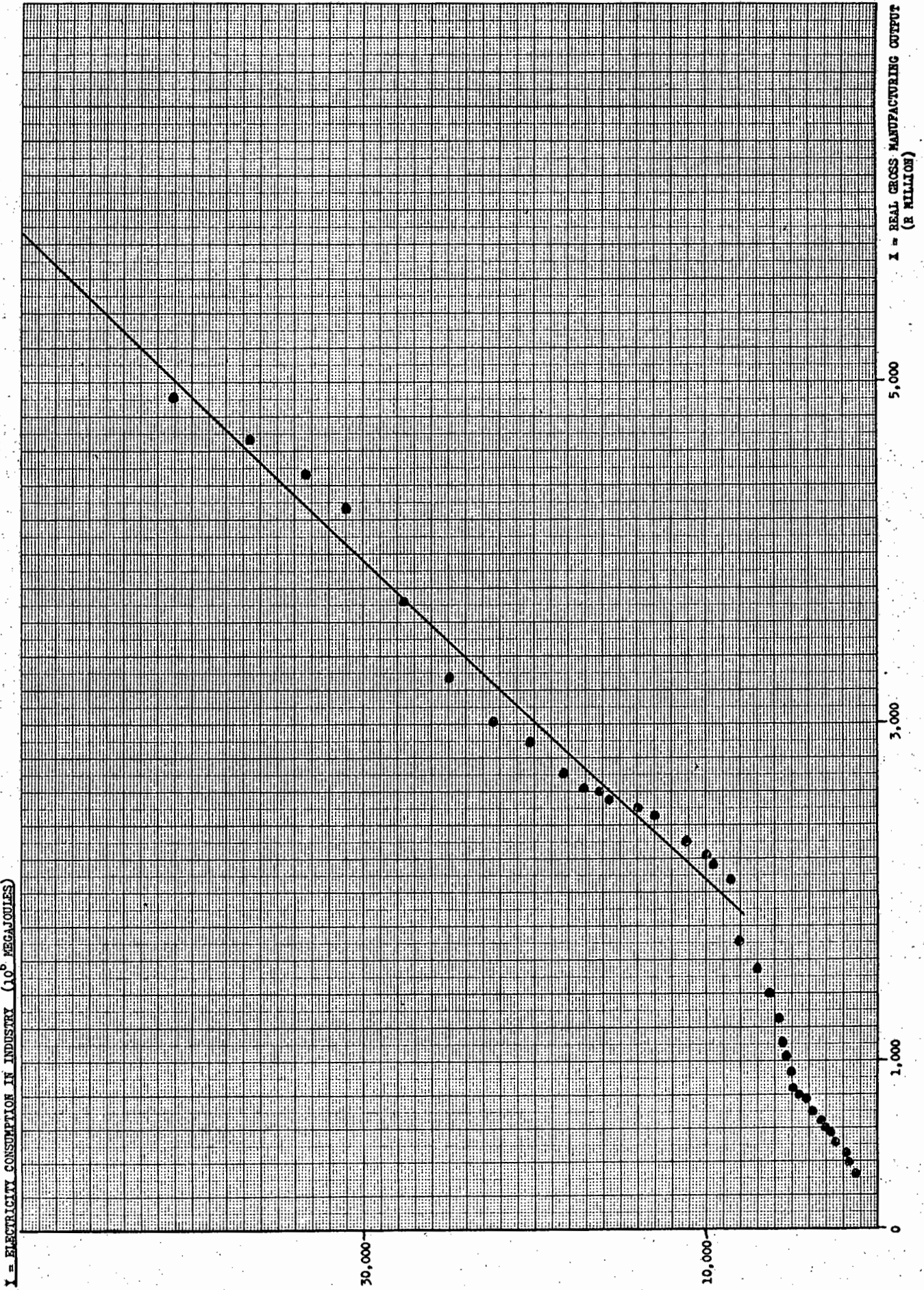
5.3.3.2 Oil

As the bulk of the petroleum demand in the households sector is caused by the agricultural tractor, a control forecast of petroleum demand in the households sector was established by using the tractor population as explanatory variable.

Fig. 49 shows the scatter diagram of the two variables; the time series on the tractor population originating from column (4), Table 32. A coefficient of correlation of 0.995 was obtained and the linear equation assumed the following form:

$$\hat{Y} = -11857.5 + 10.5471X$$

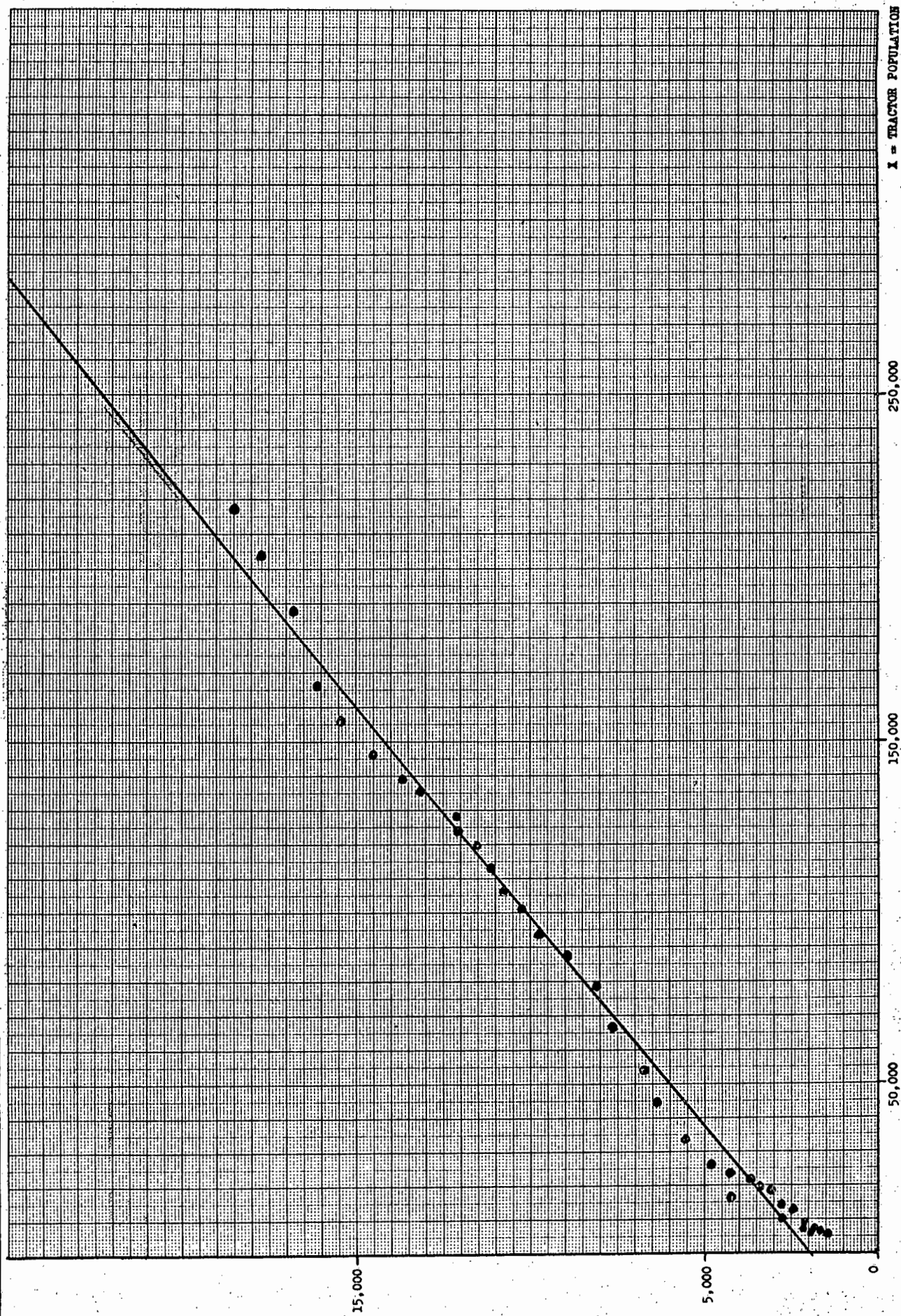
FIGURE 48: INDUSTRIAL ELECTRICITY VERSUS REAL VALUE OF GROSS MANUFACTURING OUTPUT, 1933 - 1968



$$\bar{Y} = 1996.6 + 0.08169X$$

FIGURE 49: OIL IN HOUSEHOLDS VERSUS TRACTOR POPULATION, 1933 - 1968

Y = OIL IN HOUSEHOLDS (10^6 MEGAJOULES)



X = TRACTOR POPULATION

$$Y = 1936.6 + 0.08169X$$

where Y = oil consumption in households sector

X = tractor population.

The tractor population was in turn forecast by using the real gross domestic product as explanatory variable, as shown in Fig. 50. A linear regression was performed on the observations after 1952 and a coefficient of correlation of 0.991 was obtained with equation:

$$Y = -14337 + 27.43X$$

where Y = tractor population

X = real gross domestic product

By using the forecast of real GDP, future tractor populations were obtained which again generated the forecasts of oil consumption in the households sector detailed in column (1) of Table 63.

Since the bulk of total oil demand in the transport sector is used by road motor vehicles, an independent control was established by correlating total oil demands with the motor vehicle population as economic indicator, as shown in Fig. 51. A coefficient of correlation of 0.997 was obtained with resulting equation:

$$Y = -4079.5 + 0.0433X$$

where Y = total oil consumption

X = motor vehicle population

In this way, a control forecast of total oil demands was obtained, as indicated in column (5) of Table 63.

FIGURE 50: TRACTOR POPULATION VERSUS REAL GROSS DOMESTIC PRODUCT, 1933 - 1968

$$\bar{Y} = -14337 + 27.43\bar{X}$$

Y = TRACTOR POPULATION

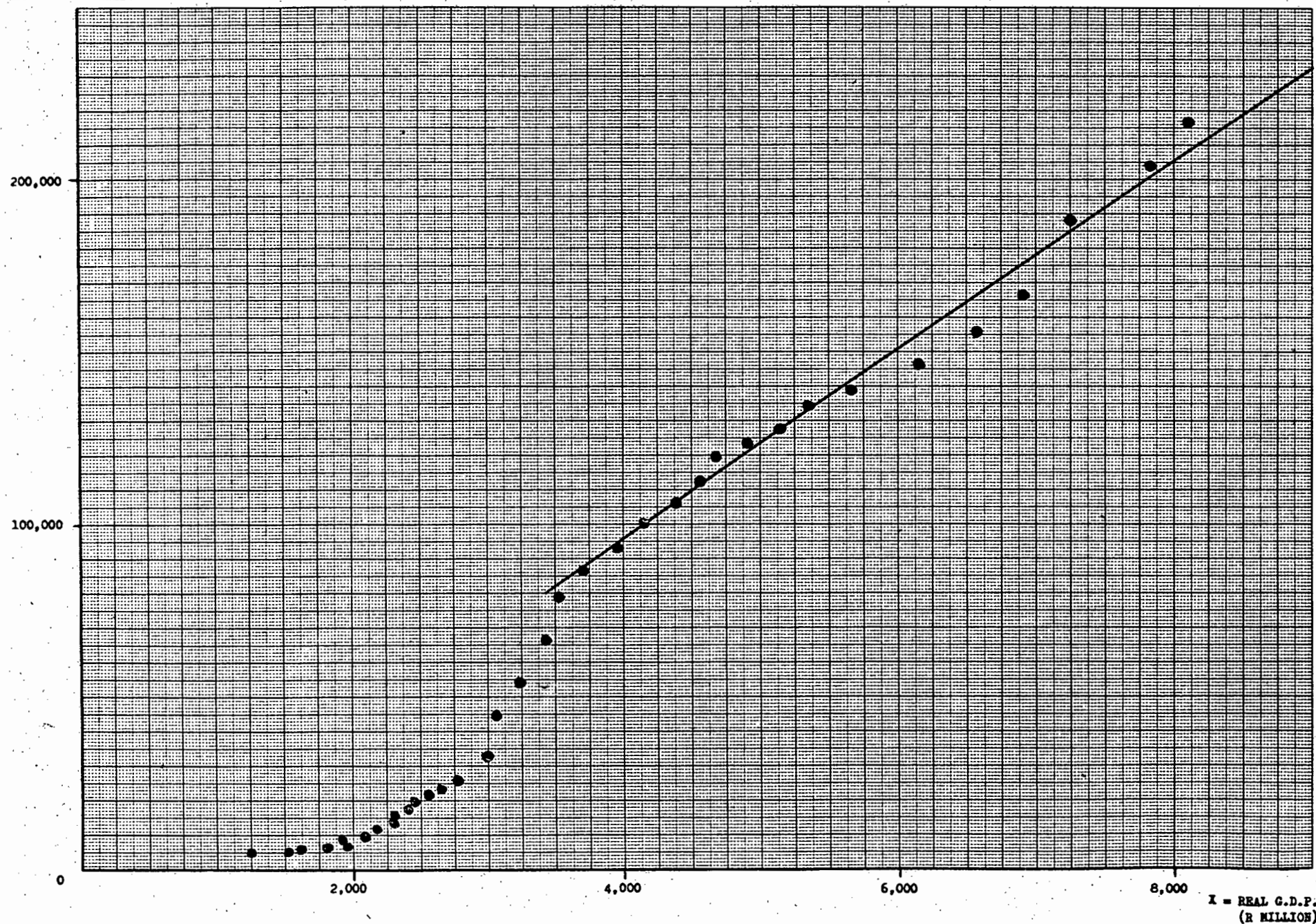
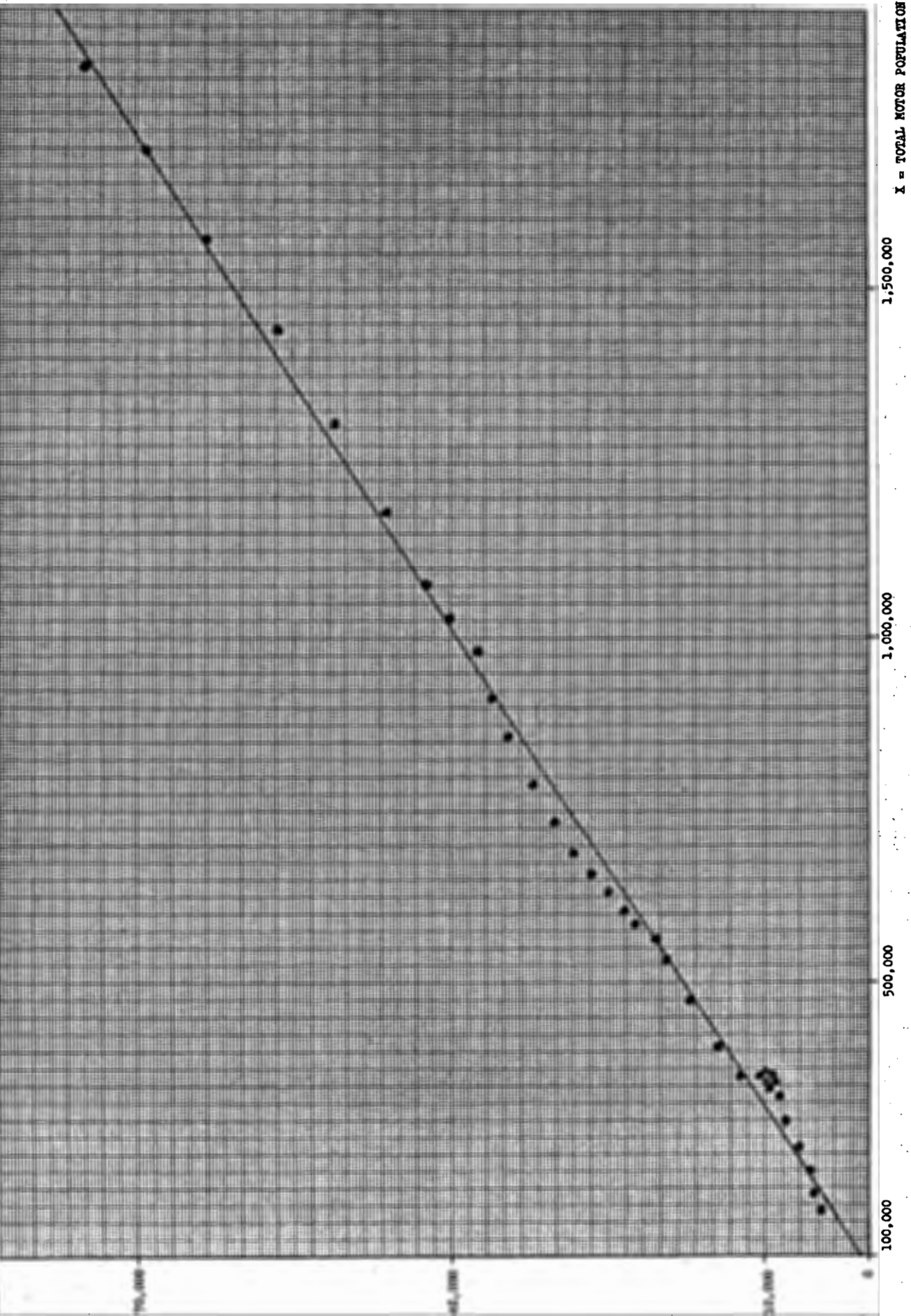


FIGURE 111. RELATIONSHIP BETWEEN TOTAL MOTOR POPULATION, 1933 - 1938
AND TOTAL CONSUMPTION OF ELECTRICITY



5.3.3.3 Coke

Coke consumption was correlated with steel production (Fig. 52); a coefficient of correlation of 0.984 was obtained with equation:

$$Y = 7672.4 + 15.2X$$

where Y = consumption of coke

X = steel production.

The series on steel production appear in column (10) of Table 46 and were obtained in a private capacity from SEIFSA. (Steel and Engineering Industries Federation of South Africa).

Steel production was, in turn, related to real gross domestic product, as shown in Fig. 53. The linear relationship yielded a correlation coefficient of 0.955 with resulting equation:

$$Y = -1173.8 + 0.681X$$

where Y = steel production

X = real gross domestic product

As before, by using the forecast of real GDP, it was possible to forecast steel production. From the latter, future consumption of coke was obtained, as given in columns (2) and (5) of Table 63.

5.3.3.4 Total energy consumption

A global energy forecast for South Africa was also made for successive years by applying Felix's technique,⁷⁹ which is based on a comparative analysis of homologous trends in different countries. In his method, Felix uses the approach of adding up the energy content of various energy-producing agents playing a part in the energy

FIGURE 52: COKE CONSUMPTION VERSUS STEEL PRODUCTION, 1952 - 1968

Y = CONSUMPTION OF COKE (10^6 MEGAJOULES)

$$\hat{Y} = 7672.4 + 15.2X$$

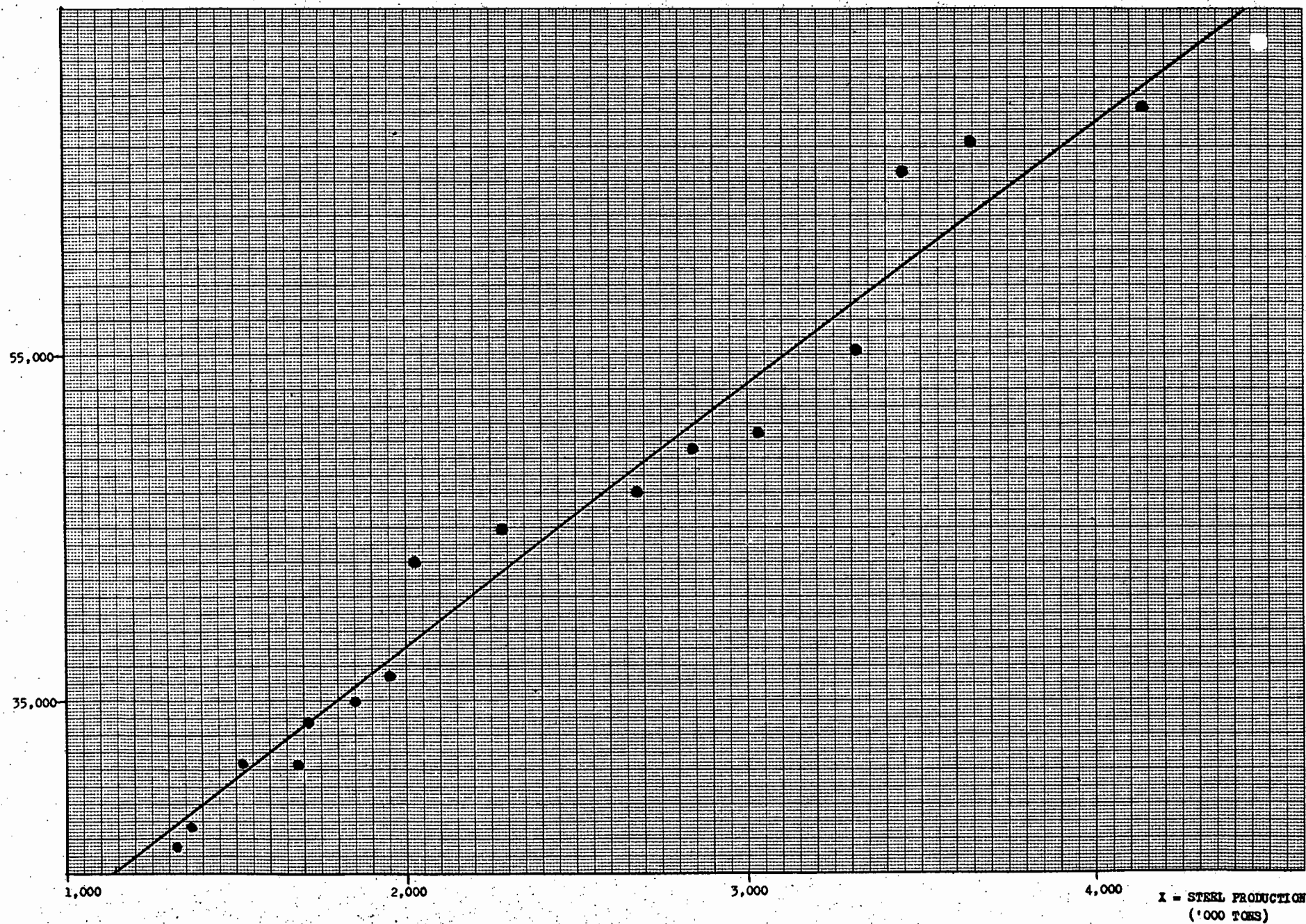
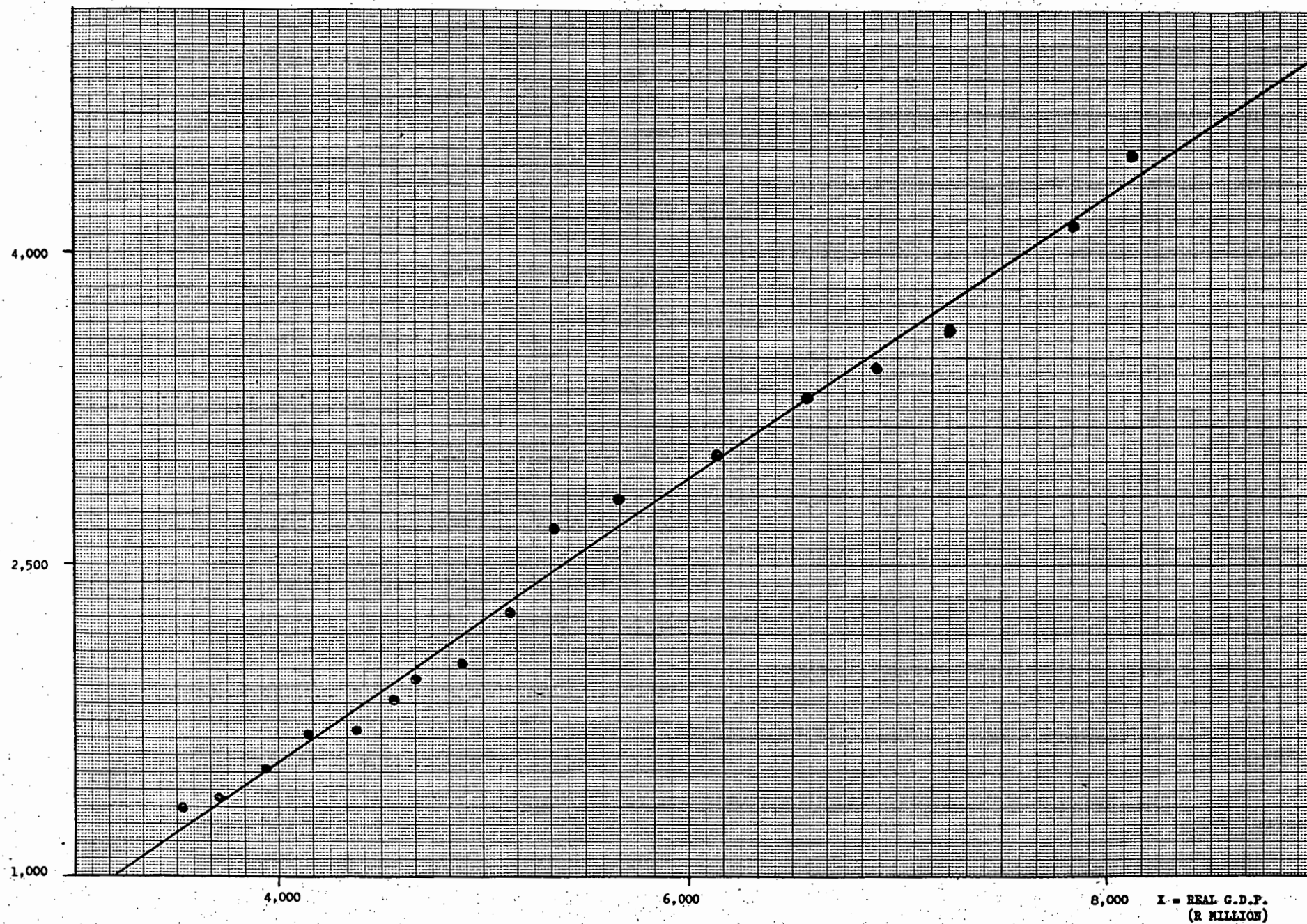


FIGURE 53: COKE CONSUMPTION VERSUS REAL GROSS DOMESTIC PRODUCT, 1952 - 1968

$$\bar{Y} = -1173.8 + 0.681X$$

Y = STEEL PRODUCTION ('000 TONS)



economies of different countries. The forecasts provided in column (5) of Table 63 are therefore based on the average growth rates implied by Felix's energy content forecasts.

Comparison of the results, detailed in Table 63, with the forecasts given in Table 60 indicates a broad agreement. The control forecasts of electricity consumption in the households and industrial sectors seem to suggest that the forecasts derived in Table 60 may be on the optimistic side. The accuracy of the latter forecasts, however, in turn seems to be indicated by the control forecast, on the total, done by Straszacker.

The control forecast of total energy consumption, using the approach of Felix, also seems to be slightly lower than the forecast provided in Table 60. (For the year 2000 the control forecast is only 72 per cent of the proposed estimate for that year.) Whether a difference of 28 per cent over a forecast period of 30 years is considered material is one matter, but another is that there are definite indications that the approach of Felix may lead to conservative forecasts, when applied to South Africa. There is clear evidence that South Africa has been progressing at a pace which is slightly ahead of the world average. One can only look at the economic growth rates experienced in South Africa over the last number of years, which were substantially higher than the world average and second only to that of Japan. Midgley^{56/} also observed the phenomenon that South Africa has been moving up the world curve, relatively, "leap-frogging" ahead of other countries.

It is, therefore, concluded that the sectoral and source energy forecasts, summarised in Table 60, are consistent, not only in relation to one another but also in relation to the total.

5.4 The supply component

5.4.1 Availability of natural resources

It is only when one comes to the forecast of how future demands for energy are going to be met that it is realised that forecasting 30 years into the future is indeed a hazardous operation. On the demand side, the task, although formidable, is relatively easier, for the basic human needs underlying the demand for energy will, in 30 years time, with minor modifications, still be very much the same as they are today. People will, for example, still need heat for cooking and mechanical power to satisfy their transport needs, irrespective of the sources of energy available to satisfy those demands. Once it becomes possible to quantify the demand for energy relative to the basic human needs generating it, an estimate of future energy demand can be made with a reasonable degree of certainty.

But it is clear that many unknown factors influence the manner in which future demands are satisfied. To begin with, if, as is believed in many quarters, the world's resources of liquid fossil fuels will be completely depleted twenty years from now, what is the sense of a petroleum consumption forecast, or production forecast, for the year 2000? Furthermore, turning to the question of technological progress, if electric cars become a practicable proposition as the result of some dramatic breakthrough, how will this influence the demand for oil and therefore the supply of it? A few paragraphs on these uncertainties and their relevance to the forecast of supply may be appropriate.

According to plausible estimates, world consumption of mineral fuels between now and the end of the century will equal about three times the amount consumed up to the present day.¹¹⁷ Since mineral fuels are depletable resources unequally distributed around the world,

it is easy to see why there should be concern about the ability of the world's resources to meet estimated future consumption.

The fact that the world's fossil fuel reserves are finite and depletion occurs at a rate which increases geometrically has led many forecasters to express their views on when the entire fossil fuels reserves of the world will be exhausted. Estimates vary in their degree of pessimism. Schumann³⁷ suggests that the notional date lies between the years 2057 and 2075, i.e. between 87 to 105 years from now.

Troost⁵³⁷ indicates that the startling increase in oil consumption led to an examination shortly after World War II of the world's potential reserves of this commodity. A survey done at the time disclosed that, at the then rate of consumption, known reserves would be exhausted in around 25 years. Intensive prospecting since then has disclosed further reserves, so that, despite the ever increasing consumption, today's reserves are larger than they were most optimistically expected to be 20 years ago. He indicates, nevertheless, that continually increasing demands will exhaust the world's oil reserves in the foreseeable future. Oil cannot therefore be relied on as a long-term provider of the world's energy requirements. As an inevitable corollary to the exhaustion of supplies, he states that the price of oil products will rise and so make their use more expensive compared to other less scarce forms of fuel.

Despite pessimism on the adequacy of the world's oil reserves in the recent and more distant past, Gonzalez¹¹¹⁷ indicated that prices of crude petroleum today are slightly below the average for 1917 - 1926.

Troost also states that the post-war survey referred to disclosed

that coal reserves were larger than oil reserves, but were also not inexhaustible. The finding is that, at the present rate of coal consumption, all known and unknown reserves throughout the world will be exhausted in less than a century.⁵³⁷

Based on an extensive study of the world's proven and inferred reserves of fossil fuel, Human¹⁴⁷ comes to the conclusion that available low cost reserves will be depleted within approximately 70 years and low and medium cost reserves in about 90 years, while total proven and potential reserves will be exhausted by the year 2070 AD.

In a recent report,³³⁷ it is indicated that the world's proved reserves of oil have risen from 4.6 billion¹⁾ tons to 46 billion tons in the past 25 years. On the other hand, the ratio between proved reserves and annual output dropped from a high of 41:1 in 1958 to 32.6:1 in 1964.

Schurr,¹¹⁷ referring to an authoritative estimate of the world's coal reserves, states that coal could supply the entire 435 billion tons of coal equivalent the world is expected to consume between 1960 and 2000, and enough coal would still remain in the ground at the end of the period to satisfy the world's total demands for energy for almost another century at the estimated annual level of consumption in the year 2000.

It is clear that any accurate evaluation of the adequacy of the world's reserves of fossil fuels presupposes a reasonable degree of certainty regarding the extent of ultimate recoverable reserves, firstly,

1) 1 Billion = 10^9

and the rate at which demand is expected to grow, secondly.

There is no agreement; in fact, there are widely differing opinions on the size and extent of world fossil fuel reserves. Schumann³⁷ puts the world's total probable store of usable energy at 4100 billion tons. An estimate entertained at the World Power Conference in 1966³³⁷ indicated aggregate ultimate reserves of fossil fuels at 6200 billion tons of coal equivalent. Human¹⁴⁷ came to the conclusion, after conducting an extensive literature survey, that total proven and inferred world reserves of fossil fuels are probably 10,383 billion metric tons of coal equivalent, Kasik¹¹²⁷ indicates proved and 'forecast' reserves at 4-5000 billion tons of coal equivalent.

On the question of estimates of future total world fossil fuel consumption, even more disagreement prevails.

In studying different opinions expressed from time to time on the subject, one is tempted to believe that in turning from estimates of energy demand to the question of the adequacy of resources one would be leaving conjecture behind and entering the realm of hard geological fact. Actually, there is no true measure of the world's endowment of energy resources, nor, in the nature of things, is there ever likely to be one. Cost alone would prohibit a comprehensive probing of the earth's crust to provide anything approaching a true measurement of resources. More to the point, society's interest is confined to resources that are exploitable now, or seem likely to be in the future. As time passes, standards of exploitability keep changing, mainly as a result of advances in technology and changes in economic circumstances. Consequently, resource-supply estimates are subject to at least as many uncertainties as energy-demand estimates. Although resource estimates embody some actual measurements of the contents of known deposits, they

are based chiefly on geological inference.

Let us consider coal first. Estimates of total resources will differ, depending on such factors as the maximum depth of coal beds to be included, their minimum thickness and whether or not the estimator is willing to include undiscovered deposits, the existence of which can be inferred. Fortunately, the differences in recent estimates are not crucial, because even the most conservative ones indicate that coal resources are enough to meet energy demands far into the future.

In considering resources of oil and gas, one encounters a category that has no exact counterpart in world coal statistics; the concept of "proved reserves". The term refers to discovered and well delineated reserves that can be extracted by available techniques at current costs and sold at current prices. Estimates of present proved reserves of oil are nearly 500 billion barrels, equivalent to 88 billion tons of hard coal, or more than 38 times world-wide consumption of oil in 1967.^{113/}

Proved-reserve figures, however, do not begin to provide a full accounting of oil and gas resources, even in well-established oil regions. The reason is that reserves cannot be proved without drilling wells, and wells are costly. Reserves are only proved, therefore, in response to explicit commercial needs. In the U.S.A., for example, proved reserves are essentially a working inventory of natural stocks. Consequently, proved reserve figures - which indicate that U.S.A. reserves will last for perhaps 12 years - are virtually useless for an analysis of the long-term adequacy of resources.

For both oil and natural gas, therefore, it is necessary to estimate "unproved" resources to obtain a figure comparable to that presented for world coal resources. Estimates of such unproved resources have generally been revised upwards over the years, but even today there are wide differences on the subject.^{117/}

These various estimates are not to be taken literally. No one really knows what the world's potential resources of coal, oil and gas are. Estimates will be revised upwards in the future, if the demand for these energy resources continues to justify the search for new deposits and there is development of new technology. Improved recovery technology alone could raise figures by a considerable percentage. For example, present-day methods yield an average of about 35 per cent of the oil known to be "in place".⁴⁷ But as recovery methods improve, so does the volume of recoverable oil. New techniques now available, if applied universally, could raise the average recovery level to about 50 per cent.⁴⁷

In addition to coal, oil and natural gas, the earth's crust contains vast potential resources of oil shale and oil bearing tar sands. The U.S.A. Geological Survey has estimated, for example, that the recoverable energy content of U.S. oil shale resources alone is about a third of the total energy content of the known and inferred coal resources (2000 billion tons) of the U.S.A.¹¹⁷ There is, therefore, reason to believe that, even without atomic energy, the world resource base of fossil fuels will amply meet requirements into the quite distant future.

Regardless of the discrepancy between particular estimates, there is reason to be optimistic about the world outlook regarding fossil-fuel supplies. The outlook is made even more promising, of course, by the advent of nuclear power.

5.4.2 Technological implications

It is clear that technological change could substantially influence, not only future demands for energy, but especially future supply patterns. Normal changes in efficiency of final consumption, or of

conversion of energy, can be described as evolutionary technological changes. However, since revolutionary technological change has radically changed patterns of energy consumption in the past, it is reasonable to expect that technological innovations will cause major shifts in future energy patterns.

For these reasons, a new approach to forecasting generally and energy forecasting particularly, has been developed, known as technological or contingency⁴⁰⁷ forecasting. This is a relatively new method of forecasting, but its procedures and techniques are being evolved rapidly. The objective of this kind of exercise in predicting the future is to speculate on what may be the impacts of alternative technological innovations on, for example, future patterns of energy demand and supply. Implied in the forecasting are the assumptions that the innovations, or technological breakthroughs, envisaged are actually feasible and that if a particular innovation is considered a worthy objective, concerted planning and direction will actually bring the innovation into existence.

An energy demand model for the U.S.A., recently completed,⁴⁰⁷ is the first major attempt in this direction. Alternative forecasts are established, which are basically exercises in technological forecasting of the energy economy, under certain contingency situations assumed for the years 1966, 1980 and 2000. Two alternative contingencies are assumed; the first is the introduction of a successful fuel-cell technology using natural gas as a fuel source, and the second is the achievement of an all-electric technology (electric cars, fuel-cell vehicles and fuel-cell power plants etc.) using various alternative fuel sources.

Since most of the more recent and expected future technological developments centre around the generation and use of electricity, it

is of interest to consider briefly the scope and promise of some methods of generating electricity, especially those which may affect the situation in future.

In earlier parts of this study, mention was made of sources of energy which may be used to generate electricity, and it was shown that nowadays nearly all commercial power is, for reasons of economy, generated either by hydro or by the combustion of fossil or nuclear fuel. In this process, the potential or heat energy is first converted into rotating mechanical energy, which is then, in turn, converted into electricity. There are a number of other generating methods which have local application and which, for the sake of completeness, may be listed as follows:-

- (i) In some volcanically active parts of the world, steam boils up to the surface from subterranean sources and has been harnessed in power stations. These plants, therefore, utilise heat from the interior of the earth. In New Zealand, about 10 per cent of all electric energy generated in 1966 was from this source, and in Italy 3 per cent.^{114/115/} Trofimuk^{116/} predicts a widespread use of the heat deep in the earth and, according to him, more geothermal plants will spring up everywhere, to make use of the heat for power and to extract a broad spectrum of useful chemicals from the steam, further freeing oil and gas for other uses.
- (ii) Attempts have been made in Russia and the U.S.A. to harness wind for the generation of electricity on a practical scale. Probably the best known installation of this type was a 1,500 kw plant on a hill named Grandpa's Knob in Vermont, U.S.A, which operated for a number of years after the last war, and was widely quoted in technical literature at the time as an outstanding success, until one day it collapsed in a storm.^{53/} It has never been rebuilt. The Russian plants have also dropped out of the news for undisclosed reasons. Nevertheless, the total world potential of wind power is estimated at 20,000 million kw.^{33/}

- (iii) Several large schemes have been investigated to harness tidal energy in parts of the world where unusually favourable conditions for these exist. The most notable probably is the Rance scheme in France, which is the only one that has in fact been built and is in operation on the French grid. Others that have been extensively investigated are at the Passamaquoddy and the Bay of Fundy schemes in North America, but these have not materialised because of economic considerations.

It is, however, universally recognised that tidal power is a barely tapped resource. An estimate of the potential for tidal power in the world has been made of 1,100 million kw.^{33/}

- (iv) Thermal gradients in the ocean and in the earth are also of local interest. A scheme has been proposed to make use of the difference in water temperature between the ocean surface, and at depth, to generate power. Up to 20°C difference in temperature is available for the purpose. In essence, this is an attempt to harness solar radiation which gives rise to the temperature difference. Success would open up a very large power source. The amount of solar energy falling on a square metre of the earth's surface in sunny areas, at and near the tropics, averaged over day and night and throughout the year, is 0.25 kw.^{53/} However, 20°C is a very small temperature difference for any heat engine to work on, and the capital cost of such a plant would be so great as to make the proposal entirely uncompetitive with other generation methods. This idea has led to some very interesting developments, mainly in Israel, where a brine of magnesium chloride is heated in large shallow "solar ponds".^{117/}

The brine in these ponds is stabilised to avoid convection currents by creating a sufficient density gradient increasing from top to bottom, i.e. having a more concentrated solution of magnesium chloride at the bottom than at the top. With this arrangement, bottom temperatures up to 90°C can be realised under ideal conditions. It is stated that a heat engine to produce power can be built in conjunction with such an installation giving an overall efficiency of 2 per cent and a power cost said to be less than 2 dollar cents per kw.h, which is

competitive with diesel engine costs, although not with steam stations.^{53/} There are, unfortunately, still a number of technical problems to be solved before success can be assured.

- (v) Many other proposals have been made to use the heat in solar radiation. Some success has been achieved in utilising this form of energy, concentrated by means of large mirrors and prisms to obtain very high temperatures in a small furnace, but, as a means of producing electric power, none of the proposals so far suggested appear to be as promising as the solar pond.

However, probably the greatest source of renewable energy is the sun. Cambel^{118/} stated that the solar radiation received on the surface of the United States is at least 1,000 times greater than that nation's use of fuels and water power. It is estimated that if 2 per cent of the United States land mass was used to recover solar energy, and if the efficiency of converting this into heat and power was 10 per cent, solar energy could enable a five-fold expansion in America's use of energy.

"Direct" methods of generating electricity

All the methods so far discussed use the intermediary of mechanical energy to effect the conversion into electricity. Naturally, a search has been made for a method to eliminate the intermediate step. Reviewing the possibilities, these are as follows:-

(i) Primary cells

The first that obviously suggests itself is the primary battery. Much research has been done in this direction. For all this, the Leclanche cell, the principle of which is over 100 years old, is still today the best and most economic primary battery.^{53/} However, the cost of power produced this way is many times that of commercially generated power, and batteries are, therefore, used for portable equipment at low consumption, where simplicity is a compelling criterion.

(ii) Fuel cells

Over a century ago, Sir W. Grove discovered the principle of fuel cells.^{119/} This British lawyer found that it was possible to realise the synthesis of water by a slow and non-exploding reaction, and that this reaction liberated a certain amount of electric energy.

The Bacon fuel cell is a device in which hydrogen and oxygen are independently introduced between a pair of electrodes, and the chemical combination produces a potential difference between the electrodes. Unlike a primary battery where the power is limited by the chemicals provided ab initio therein, the fuel cell will produce energy as long as the reagents are fed in. There is still a great deal of development to be done on such possibilities as replacing hydrogen by hydrazine, which is a more manageable fuel, but units of up to some 20kw have been made. One large U.S. firm, about 5 years ago, demonstrated a fuel cell-propelled tractor as part of their research and development programme for wider application, and now the Apollo series of spacecraft use this type of power supply for their internal requirement.

The characteristics of fuel cells such as high conversion yield, increasing when the cell is not performing at full output, and operation without noise or toxic emission should result in their application increasing considerably, and progressively.

In the first phase, cells ranging from a power of a few watts to kilowatts will replace conventional cells, batteries and even stationary or portable generating sets, thus contributing to the solution of noise and air pollution problems.^{119/}

When the cells become lighter and cheaper, their use will be particularly suitable for the propulsion of electric trucks, mechanical handling and public transport. Their use is also foreseen for trains and ships.

Fuel cells are now operating in several countries and have reached the industrial development stage.^{119/}

(iii) Thermo-electric Converters

When certain dissimilar metals are joined in a circuit and the one junction is heated, whilst the other is kept cold, the current will flow in the circuit. This current is a function of the temperature difference between the junctions. The usual application of this phenomenon in the past has been in temperature measurement where platinum/platinum rhodium alloy and chromel/alumel junctions are employed. Recently a number of small generating systems producing a few watts output, using this principle, have been built, mainly in the U.S.A. These have been used for such purposes as to power weather buoys out at sea, observation probes sent out into space, landed on the Moon or Mars etc. The heat source used in these devices is long-life nuclear materials such as radioactive caesium krypton, cerium 144, and the like.^{53/}

(iv) Photo Electric Devices

The photo-electric cell has been used for many years to switch on street lights, in light meters for photography and in electronic circuitry of various sorts. The functioning of this equipment depends on the property of some substances to give off electrons when light falls on them. For space exploration, devices of this type, now generally known as solar cells, have been developed to power the various satellites, especially the smaller unmanned equipment probes. Power output is DC like all cell-type equipment and power outputs of 1 - 50 watts can be obtained in arrays of acceptable size. As a large number of cells, 10,000 or more, can be accommodated in an array, considerable possibilities of current and voltage ranges are available. Cell voltage is appreciably affected by temperature conditions.

(v) Magnetohydrodynamics (MHD)

The MHD generator converts the thermal energy of a conducting fluid to electrical energy via the interaction of the motion of the fluid with a magnetic field. If significant power is to be produced by the generator, the moving fluid must have a large number of free electrons (i.e. high conductivity.) For a gas,

the free electrons are obtained by either heating the gas to a sufficiently high temperature to produce the plasma, or seeding the gas with an element or compound which ionizes at relatively lower temperatures. If the fluid is a liquid, a metal having a low melting temperature is desirable.^{120/}

MHD may be divided into two broad classifications: open cycle MHD using the combustion of a fossil fuel as a source of heat, and closed cycle MHD using primarily nuclear heat. Because of their high operating and exhaust temperatures, MHD generators are best suited as topping devices for conventional steam cycles.

Theoretically it can be shown that with a high temperature, say 2000 to 5000°F, such as can easily be reached with gas from a furnace or a nuclear reactor, a very high thermal efficiency of conversion can be achieved - up to 60 per cent being theoretically attainable. Also with high velocities and large ducts much power can be generated, and, on paper, the process is highly promising as a potential competitor to the more conventional boiler - turbogenerator power plant. Intensive research has, therefore, been done in the U.S.A., U.K., France and many other countries on the practical development of this idea. The principle is so attractive, particularly because it can conveniently be made to generate AC as well as DC, that it will continue to be investigated and it may eventually be developed into a commercial proposition.^{53/}

Apart from technological factors influencing future generation and supply of electricity, there are many other significant areas where innovation can conceivably affect the future course of the energy economy. The advent of nuclear energy which has only recently made its debut has far reaching implications. According to current world forecasts, nuclear energy will account for about 18 per cent^{121/} of total energy consumption by the turn of the century. Much is expected of the development of economic breeder reactors. It is principally in the electricity generation field that nuclear energy will increasingly compete with other fuels.

In the distant future, nuclear fusion using heavy hydrogen (deuterium), which is in abundant supply in sea water, may eventually become controllable.

Nuclear fusion is also safer than nuclear fission as it yields no radioactive waste.^{120/} This development could realise an almost boundless source of energy. Experts hold, however, that 15 - 20 years work is required to produce even a satisfactory laboratory demonstration, and commercially competitive fusion energy is unlikely before the end of the century.^{4/}

Lastly, many researchers suggest that coal will feature prominently as a source of hydrocarbon fuels simply because the reserves of coal far exceed those of any other hydrocarbon. Information available on two processes recently developed; the so-called Consolidation Coal direct-hydrogenation process (CONSOL), and the H-coal process, seems to suggest that these processes are capable of producing petrol at 11 cents (U.S.)^{33/} per gallon, and that this development will become commercial in the early 1970's. Recently a pilot plant was initiated at Cresap, West Virginia, U.S.A.. Supporters of the Cresap project say gasoline can already be made from coal at a cost of 11 (U.S.) cents a gallon, a competitive figure.^{123/} Many oil companies have hedged against a future development of this nature by the acquisition of coal-fields.^{124/}

To what extent are these considerations allowed for in the energy supply forecast? The approach followed was to allow for the effect of certain types of evolutionary technological change which can be quantified at this stage with a reasonable degree of certainty. No allowance has been made for major revolutionary technological developments, as this will essentially embody the presentation of a number of supply forecasts based on alternative contingency assumptions. The contribution made at present must be seen as the logical outflow of present known trends. On this hypothesis may of course be superimposed alternative contingency assumptions, as more clarity becomes available.

5.4.3 The supply forecast

The spectrum of future demand, by sector and by form of energy, is now available, as given in Table 60. Demand forecasts for the various energy-producing agents, as expressed in megajoules, have therefore been reconverted to their customary units, as originally presented in the historical energy balances. To this end, the efficiencies detailed in Table 35 were used, yielding future estimates of different sources, for 1980, 1990 and 2000, as presented in Tables 64, 65 and 66, respectively.

Having obtained final demand, it is now possible to complete the conversion sector, by applying the technical coefficients defined in Section 3.3. This approach is, however, not feasible owing to lack of detailed data in the historical conversion matrices. Instead, production and total consumption will be derived for each form of energy based on separate hypotheses applying to each characteristic form.

5.4.3.1 Electricity

Nuclear electricity

Production of nuclear electricity is calculated by accepting the most authoritative estimate available on future South African nuclear capacity, namely that of Human.¹⁴⁷ Human predicts installed nuclear capacities of 580 MW by 1980, 4057 MW by 1990 and 26257 MW by 2000. (See Section 2.3.3.2, page 155). Since cost analyses underlying these estimates of nuclear capacity are based on the economics of the Boiling Water Reactor (BWR), a load factor representative of proven BWR performance has been employed. Load factors of BWR reactors in the U.S.A. range between 80 and 90 per cent. Nuclear power plants are normally operated as base-load stations. The lower limit of 80% was accepted as a basis for this study.

TABLE 64: ENERGY BALANCE, 1980

CONSUMPTION SECTOR	ENERGY SOURCE	ELECTRICITY				GAS		LIQUID FUELS		SOLID FUELS		
		TOTAL	THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH				MILLION CUB. FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		14580				1478		23867		3971		17
2. INDUSTRY		38950				13009	155388	35605		5952	7858	38
3. MINING		16841						992		1695		
4. TRANSPORT		4794						65317		4499		
5. INLAND FINAL CONSUMPTION (1 - 4)		75165	64893	6856	3416	14487	155388	125781		16117	7858	55
6. IMPORT BALANCE INCL. BUNKERS		6013		6013				(42476)	184276			
7. FINAL DEMAND (5 - 6)		69152	64893	843	3416	14487	155388	168257	(184276)	16117	7858	55
8. THERMAL STATIONS		12330	12330					140		37956		
9. HYDRO STATIONS		160		160								
10. NUCLEAR STATIONS		649			649							
11. COAL GAS PRODUCERS						435		193		597		
12. OTHER GAS PRODUCTION												
13. REFINERIES								8873	186336	1970		
14. CRUDE PRODUCTION												
15. MINES										1395		
16. COKE PRODUCERS										11728		
17. GAS COKE PRODUCTION												32
18. PRODUCTION (7 - 17)		82291	77223	1003	4065	14922	155388	177463	2060	69763	7858	87
19. TOTAL CONSUMPTION (6 + 18)		88304	77223	7016	4065	14922	155388	134987	186336	69763	7858	87

TABLE 65: ENERGY BALANCE, 1990

CONSUMPTION SECTOR	ENERGY SOURCE	ELECTRICITY				GAS		LIQUID FUELS		SOLID FUELS		
		TOTAL	THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH				MILLION CUB. FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		27860				1478		40897		3778		17
2. INDUSTRY		86503				24111	307734	59243		8323	14416	38
3. MINING		22765						1306		2075		
4. TRANSPORT		7977						112398		3298		
5. INLAND FINAL CONSUMPTION (1 - 4)		145105	109303	11910	23892	25589	307734	213844		17474	14416	55
6. IMPORT BALANCE INCL. BUNKERS		11608		11608				(89539)	333776			
7. FINAL DEMAND (5 - 6)		133497	109303	302	23892	25589	307734	303383	(333776)	17474	14416	
8. THERMAL STATIONS		20768	20768					210		63932		
9. HYDRO STATIONS		57		57								
10. NUCLEAR STATIONS		4539			4539							
11. COAL GAS PRODUCERS						768		259		1054		
12. OTHER GAS PRODUCTION												
13. REFINERIES								15992	335836	1970		
14. CRUDE PRODUCTION												
15. MINES										2100		
16. COKE PRODUCERS										21516		
17. GAS COKE PRODUCTION												32
18. PRODUCTION (7 - 17)		158861	130071	359	28431	26357	307734	319844	2060	105046	14416	87
19. TOTAL CONSUMPTION (6 + 18)		170469	130071	11967	28431	26357	307734	230305	335836	105046	14416	87

TABLE 66: ENERGY BALANCE, 2000

CONSUMPTION SECTOR	ENERGY SOURCE	ELECTRICITY				GAS		LIQUID FUELS		SOLID FUELS		
		TOTAL	THERMAL	HYDRO	NUCLEAR	COAL GAS	OTHER GAS	REFINED	CRUDE	COAL	COKE OVEN COKE	GAS COKE
		MILLION KWH				MILLION CUB. FT.		'000 BARRELS		'000 TONS		
1. HOUSEHOLDS		51230				1478		67901		3121		17
2. INDUSTRY		176230				42014	567187	82750		11843	24864	38
3. MINING		30652						1737		2661		
4. TRANSPORT		12839						188835		2130		
5. INLAND FINAL CONSUMPTION (1 - 4)		270951	101932	14390	154629	43492	567187	341223		19755	24864	55
6. IMPORT BALANCE INCL. BUNKERS		14147		14147				(188748)	584246			
7. FINAL DEMAND (5 - 6)		256804	101932	243	154629	43492	567187	529971	(584246)	19755	24864	
8. THERMAL STATIONS		19367	19367					150		59621		
9. HYDRO STATIONS		46		46								
10. NUCLEAR STATIONS		29380			29380							
11. COAL GAS PRODUCERS						1305		347		1792		
12. OTHER GAS PRODUCTION												
13. REFINERIES								27919	586306	1970		
14. CRUDE PRODUCTION												
15. MINES										2454		
16. COKE PRODUCERS										37110		
17. GAS COKE PRODUCTION												32
18. PRODUCTION (7 - 17)		305597	121299	289	184009	44797	567187	558387	2060	122702	24864	87
19. TOTAL CONSUMPTION (6 + 18)		319744	121299	14436	184009	44797	567187	369639	586306	122702	24864	87

Own use and loss equals 19 per cent of final consumption, which is the same as forecast for thermal power plants.

Hydro-electricity

(a) The Orange River Scheme

Official indications of installed hydro-electric capacity of the Orange River Scheme have been used. (See Section 2.3.2, page 139). These decline from 229 MW in 1980 to 82 MW in 1990 and to 66 MW in 2000 due to diminishing supplies of water as consumptive demand increases. A load factor of 50 per cent throughout was built in, which is universally representative of hydro-plants.

Own use and loss equals 19 per cent of final consumption.

(b) Imports from Cabora-Bassa

In Section 2.3.2.2 it was recorded that South Africa has agreed to purchase the output of 1000 MW by 1974, rising to 1700 MW by 1980. The principle was, however, also accepted that such purchases will not exceed 8 per cent of the country's requirements in a given year. It was found, on the basis of the 3 forecast years selected, that the output of 1700 MW will only be bought by the year 2000, since it far exceeds 8 per cent of aggregate national demand in 1980 and 1990. Imports of Cabora Bassa power, therefore, equal 8 per cent of total inland final consumption in 1980 and 1990 and is equivalent to the output of 1700 MW in 2000.

Thermal electricity

Final demand for thermal electricity is established by subtracting, from total demand, combined forecast sales of hydro - and nuclear power.

From the historical energy balances it was clear that the ratio of own use and loss to sales fluctuated around 19 per cent over a period of over 30 years. It was, therefore, assumed that this percentage will continue to apply over the forecast period.

In this way, forecast indigenous production and total consumption of thermal-hydro, nuclear and total electricity are derived as shown in Tables 64, 65 and 66.

5.4.3.2 Coal gas

Traditionally, own use and loss of town-gas producers is about 3 per cent of total sales. By extrapolation of this percentage, production and therefore total consumption is obtained.

5.4.3.3 Other gas

As was indicated in Section 3.5.2, it has not been possible to obtain historical information on own use and loss for this form of energy. Production of other gas is therefore taken to be the same as final demand.

5.4.3.4 Refined oil

The volumes of refined product indicated in the row of the import balance (row 6) are estimates of future international bunker off-takes at South African ports and are therefore really treated as exports - hence a negative import balance.

It was observed that international bunker demand prior to 1967, i.e. before the last Suez crisis, correlated fairly well with aggregate statistics of imports and exports. By using the historical relationship,

it was found that normal demand for bunkers would increase, on the average, at about 8 per cent annually. The Suez closure had of course the effect of violently increasing bunker demand during 1967 and thereafter.

Ironically, an assumption on the continued closure or re-opening of Suez is necessary before future bunker demand can be predicted. For the purposes of this study it was assumed that current total bunker demand; in other words, 'normal' bunkers plus diverted bunkers, will in future continue to grow at the rate at which normal bunkers is expected to grow, or at 8 per cent per annum. In view of the large volume exported in this manner at present, the forecast of bunker demand by 2000 is quite substantial, amounting to almost 40 per cent of final demand.

A small amount of petroleum will, it is expected, continue to be used by small sets (in inaccessible rural areas) and as start-up fuel in thermal power stations, hence the entry in row 8.

The petroleum input into the coal gas category is in accordance with expected growth of town gas producers, excluding the Johannesburg Municipal Gas Works and Gascor, and must be read in conjunction with the comments made on coal gas in Section 5.3.2.1.

Refinery yields experienced universally show that about 95 per cent of refined product is obtained from a barrel of crude. If the total of rows 7 to 11 be taken as 95 per cent, production is derived and the difference (row 13) amounts to refinery's own use and loss. This practice is projected into the future, the implication being that South African refining capacity will be sufficient in 1980 and thereafter to cater for onshore and offshore demand for refined product.

5.4.3.5 Crude oil

As no local crude oil production is assumed over the forecast period, as stated in Section 5.2; all requirements will be imported, except the small production of synthetic crude by Sasol.

As is observed in Tables 64 to 66, neither expansion of the current Sasol oil from coal production nor the erection of further installations of this nature is envisaged. The current Sasol oil from coal economics compare unfavourably with conventional petroleum production. Furthermore, it appears likely that the authorities will first wait for the outcome of local exploration for oil now in progress. The progress on H-coal and Consol technologies are no doubt also keenly awaited.

Refinery runs of crude oil (row 13) equal production and own use and loss of refined product; no allowance is being made for building-up of crude stocks as the latter are influenced by strategic or policy considerations which, in turn, may depend on environmental imponderables.

The difference between rows 13 and 18, of course, equals imports of crude oil, indicated in the import balance.

5.4.3.6 Coal

Coal demands appearing in row 8 are inputs allocated to thermal power stations and are a function of final consumption of thermal electricity. These demands have been established for 1980 and thereafter on the assumption that the bulk of thermal power will be generated at the large pithead power stations located in the Eastern Transvaal. Thermal efficiencies and average calorific values for coal burnt are therefore representative of conditions applying to power generation in this area. It was, for instance, established that the Btu consumed per kwh sold for the Eastern Transvaal Undertaking of Escom equalled 12400⁵²⁷ in 1969. This

figure was employed up to the year 2000, as it was already indicated that sizes of installed and planned capacities of thermal power stations in the region are such, suggesting that optimum thermal efficiency has been achieved. The average calorific value of coal burnt by the Eastern Transvaal Undertaking in 1969, of 10600 Btu per lb.,⁵²⁷ has similarly been applied in forward estimates.

A fairly constant ratio between coal consumption and coal gas output was extrapolated and coal demand by coal gas producers obtained for forward years.

The Sasol demand for coal for usage in the oil from coal process, as already discussed, is held constant, as shown in row 13. If the promising processes referred to earlier become a practicable economic reality, coal demand in this category could of course be infinitely higher than indicated. The assumption that this will eventuate reduces the exercise to a contingency forecast, a procedure which is as far as possible avoided here, for reasons already discussed.

The demands for coking coal are of course derived from the forecast of coke consumption, applying the ratio used to estimate historical consumption of coke, as outlined previously in Section 3.5.4. On the average, a ton of coking coal yields about 67 per cent, by weight, of coke.

It was established that, historically, own use and loss of coal mines fluctuated very closely around 2 per cent of production. In extrapolating this ratio, own use and loss and, by addition, production are obtained.

It will be observed from the tables that no allowance for exports of coal is made.

Dealing firstly with coking coal. In the neighbouring column an indication is given of future magnitudes of coke-demand. It is clear that they are substantial. Seen in the light of a relative shortage of coking coal reserves in the country, it will be the height of folly to suggest that coking coal should be exported, no matter how dire the shortage in Japan, or elsewhere in the world, may be.

Secondly, as already mentioned in Section 2.2.5, it is indicated that new techniques have been introduced into steelmaking and these, requiring heavy introduction of anthracite for sintering purposes, can open up export possibilities for South African anthracite. As was seen in Table 16 and in the section where coal reserves were discussed, local reserves of anthracite, or other high quality coal for that matter, are also in short supply. Given the enormous demand envisaged for coking coal, it is common sense that one would not entertain ideas on the exportation of anthracite if the likelihood exists that the product could now or in future be required by the local steel industry.

Lastly, turning to bituminous coal. It will be seen in the next section that saleable coal reserves of South Africa are not large in the light of projected demand. Exports of large quantities of coal can therefore not be entertained. Furthermore, on the basis of the indicated revenue to be derived from such exports, and considering the enormous capital outlay for bulk installations and facilities at harbours and elsewhere implied by the vast quantities necessary for its economic justification, as well as the demands on the rail transport system, the observer cannot but come to the conclusion that there are other more urgent economic priorities, apart from the well-established principle of optimum use of available scarce resources.

5.4.3.7 Coke

In the absence of adequate historical data on the partial energy balance for this source, as discussed in Section 3.5.4, production is assumed to be the same as consumption.

5.4.3.8 Gas coke

The figures appearing under this heading, which have been rationalised in Section 5.3.2.1, apply to the Johannesburg Gas Works.

5.4.4 Conclusions

5.4.4.1 Electricity

Owing to future projected contributions from hydro-electric and nuclear sources, the share of thermal electricity consumption in the total is expected to drop from 100 per cent in 1968 to 86 per cent in 1980, to 82 per cent in 1990 and to 40 per cent in 2000. Stated differently, it means that the demands on thermal power stations, which have grown at 7.5 per cent on the average annually, over a long period, will decline relatively and are now expected to grow at 5.4 per cent annually between 1968 and 1980 and between 1980 and 1990. After 1990, absolute consumption of thermal electricity will decrease; the estimate for 2000 being 7 per cent lower than for 1990. It is clear that these developments will have important implications on fossil fuelled thermal power stations in South Africa.

5.4.4.2 Liquid Fuels

In order to consider trends in the production of refined product in proper perspective, it is necessary to look at inland demand and bunkers separately. Inland demand, which has grown on the average annually at 7.5 per cent over the last twelve years, is expected to grow at 8.7 per

cent annually between 1968 and 1980, 5.5 per cent annually between 1980 and 1990 and 4.8 per cent annually from 1990 to 2000. The increased rate of growth between 1968 and 1980 is the result of increased fuel oil offtakes due to displacement of coal in the industrial sector.

Bunker demand is forecast to grow at about 8 per cent per annum.

As a result of these trends, production of refined product (in order to remain self-sufficient in local production) will have to increase at no less than 12.6 per cent annually 1968 through 1980. This percentage will level off to 6.0 per cent for the decade 1980 to 1990 and 5.6 per cent between 1990 and 2000.

The implications of these developments on the local oil industry are considerable and point to a requirement for enormous capital investment for refinery expansion, especially over the next 12 years.

5.4.4.3 Solid Fuels

The future demand pattern of coal can now be established from Table 64 to 66. This is done in Tables 67 and 68. Definitions of the columns of these tables correspond to those discussed for Table 18.

From Table 67 it is evident that total demand for coal is expected to grow by 1.9 per cent on the average annually between 1968 and 1980, by 4.5 per cent annually between 1980 and 1990 and 1.3 per cent annually between 1990 and 2000.

The small increase between 1968 and 1980 is due to the combined effect of the displacement of coastal coal in the industrial sector and smaller growing offtakes by the electricity generating industry, owing (mainly) to importation of Cabora Bassa hydro electric power.

TABLE 67: FORECAST BY SECTOR OF TOTAL COAL CONSUMPTION, 1968 TO 2000

YEAR	ELECTRICITY GENERATION	RAILWAYS	COKE PRODUCERS	COAL GAS PRODUCERS	MINING	SASOL	INDUSTRY	DOMESTIC	TOTAL CONSUMPTION
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1968	28,660	6,459	5,864	366	1,505	1,970	6,017	3,494	54,335
1980	37,956	4,499	11,728	597	1,695	1,970	5,952	3,971	68,368
1990	63,932	3,298	21,516	1,054	2,075	1,970	8,323	3,778	105,946
2000	59,621	2,130	37,110	1,792	2,661	1,970	11,843	3,121	120,248

TABLE 68: PERCENTAGE CONTRIBUTION TO TOTAL COAL CONSUMPTION FOR EACH SECTOR, 1968 TO 2000

YEAR	ELECTRICITY GENERATION	RAILWAYS	COKE PRODUCERS	COAL GAS PRODUCERS	MINING	SASOL	INDUSTRY	DOMESTIC	TOTAL CONSUMPTION
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1968	52.7	11.9	10.8	0.7	2.8	3.6	11.1	6.4	100.0
1980	55.4	6.6	17.2	0.9	2.5	2.9	8.7	5.8	100.0
1990	60.3	3.1	20.3	1.0	2.0	1.9	7.8	3.6	100.0
2000	49.6	1.8	30.9	1.5	2.2	1.6	9.8	2.6	100.0

After 1980, and up to 1990, growth increases as displacement in the industrial sector will have been completed and the initial impact of alternative supplies of electricity has been weathered.

Between 1990 and 2000, growth levels off again as a result of the rapid introduction of nuclear power.

These trends are depicted in Figure 54.

The findings on the demand for coal in the mining sector, as shown in columns (5) of Tables 67 and 68, perhaps warrant a comment. It is noted that, although the share of coal consumed in this category declines, offtakes actually increase. This is of course unrealistic, as can be seen in the light of the historical statistics appearing in column (7) of Table 18.

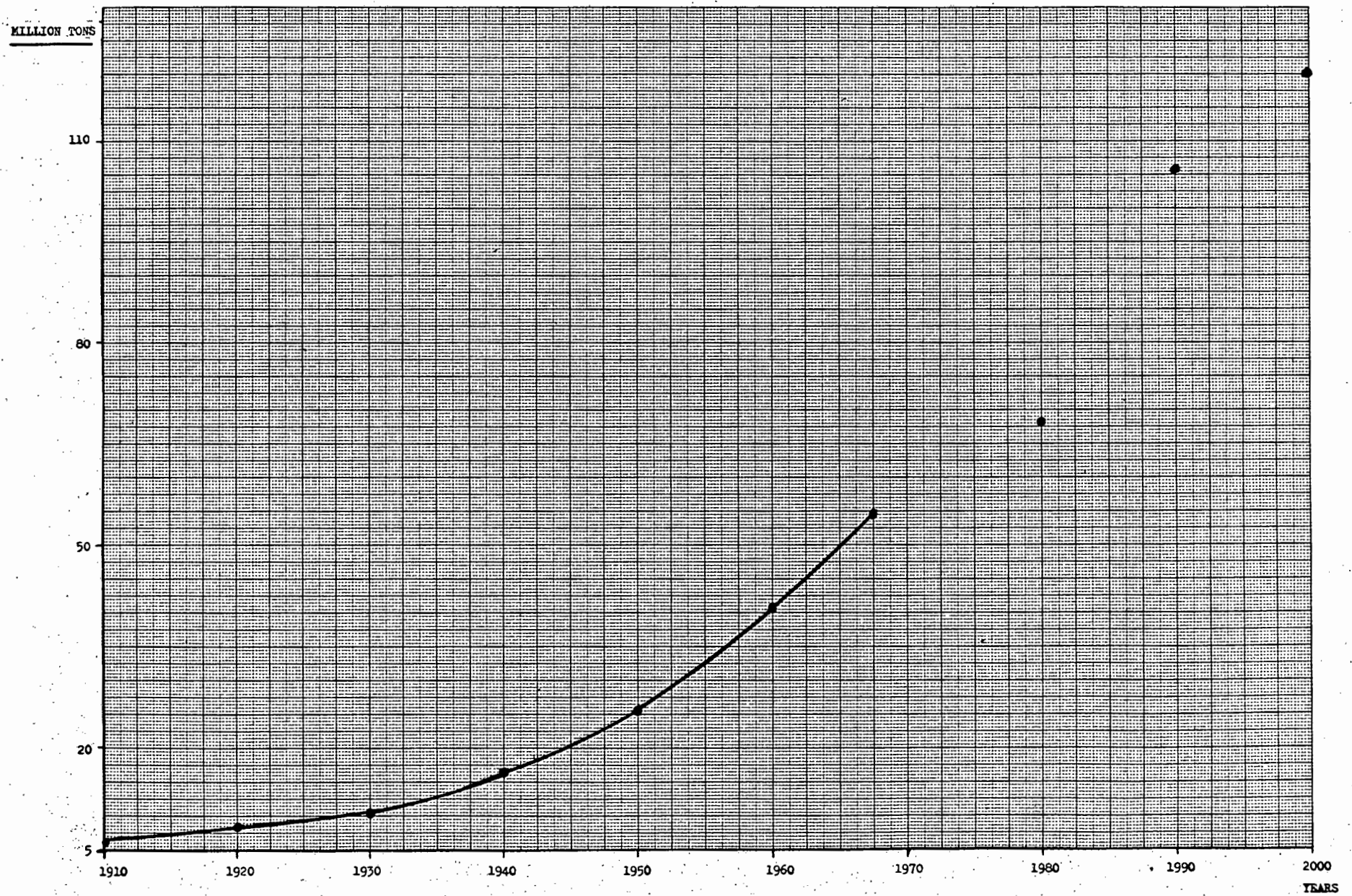
In retrospect, it now appears that using the modified exponential function (Fig. 32), from which the coal forecast in the mining section has been derived, resulted in an over-optimistic forecast in this category. It seems as if a straight line would have been the more appropriate relationship. This has, of course, the implication of a slightly conservative electricity forecast in the mining sector and, consequently, in the total.

However, it can be seen in Tables 67 and 68 that the relative magnitudes involved are so small that it is really of minor consequence.

What are the implications of these demand trends on present indications of saleable coal reserves, as detailed in Table 16?

From Table 67 it is evident that demand will grow on the average annually between 1968 and 2000 at 2.5 per cent. Summation of the geometric series indicates that cumulative demand over the 32 year period amounts to 2624 million tons, or 23 per cent of saleable reserves of

FIGURE 54: HISTORICAL AND FORECAST CONSUMPTION OF COAL, 1910 TO 2000



11558 million tons, as established in Table 16.

Fig. 54 indicates a levelling off of the rate of increase of demand after 1990. The average annual increase in demand during the last decade of this century is in fact 1.3 per cent annually. If it is assumed that demand will continue to grow at 1.3 per cent annually beyond 2000 (the most optimistic alternative indicated by the general trend, especially in view of the escalating influence of nuclear generation), it is possible to estimate the life expectancy of available coal reserves.

This is done by taking undepleted reserves in the year 2000, equalling 8934 million tons ($11558 \times 10^6 - 2624 \times 10^6$ tons) and solving the equation by summation of the geometric series which increase by 1.3 per cent annually.

On this basis, it is established that available reserves will last for another 84 years after 1968, or, to provide a notional date, the year 2052 AD.

These findings essentially reinforce views on the adequacy of South Africa's coal reserves expressed in the Report of the Coal Advisory Board.^{33/} If the promising technology on oil from coal production does eventuate, it will be found that the indicated life expectancy of 84 years will be far too optimistic.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

In this study a survey was conducted of all the methods applied in the world today for a systematic analysis of the energy economy. These methods have been identified, examined and studied to establish whether they are suitable for a satisfactory analysis of the South African energy economy.

Following from the above, an attempt was mounted to systematically collect all the relevant statistical information on the different branches of the energy industry, which would enable a thorough analysis of the energy economy. This resulted in the construction of the historical energy balances for South Africa, a practice without which neither a satisfactory analysis nor forecast of the energy economy is possible.

The methodology of forecasting, generally, and energy forecasting, particularly, was examined and available tools or techniques were selected and adapted to suit local requirements.

An analysis and forecast of all the stages of the energy economy in South Africa were made and inference was drawn regarding methodological considerations, on the one hand, and the physical implications on the energy economy, on the other.

6.2 Conclusions

On methodological problems associated with the analysis of the energy economy, it was established that individual application of available methods is largely dictated by conditions characteristic of a particular country and by the nature of the problem at hand. Because of differences in efficiency applying to the conversion and final consumption of different energy sources, the method of equivalence of the useful effects of energy was found to be a more accurate approach to the problem in South Africa. This is further reinforced by the preponderant part played by coal in the local energy economy.

Regarding the question of availability of sufficiently detailed statistical information on which the success of an analysis and forecast of the energy economy depends, the view is held that much more can be done officially. It is imperative that the country make appropriate administrative arrangements for the systematic collection, compilation and, where necessary, dissemination of all relevant data on the different branches of the energy industry. To be of practical value these data must cover as long a period as possible. Moreover, up-to-date compilation of current statistics is important in taking appropriate measures to correct deficiencies, imbalances and bottlenecks that may be brought to light. The individual branches of the industry - coal, oil and electricity should organise data relating to their respective areas, and these should be properly collated and compiled by a governmental body established for this purpose.

Collection and compilation of statistical data on energy will undoubtedly call for a sizeable budget provision and for personnel, but owing to the pressing demands from various other sectors of the economy the Government has probably allotted a relatively low priority to such projects.

Therefore, as these data are primarily and directly of use to the energy industries themselves, both in terms of their short and long term programmes, it is most important that the energy industries organise and strengthen their own statistical divisions. The expenses will be amply repaid by the improved working and planned growth of the economy.

Turning to the methodology of energy forecasting, it was established that energy forecasting must essentially be done in two stages. First, final demand and, then, primary demand is estimated. Generally, energy changes its form and efficiency in the flow of goods - in the process of production, conversion, transport, distribution and utilization. An energy balance has to be drawn up as accurately as possible, in the preparation of which it is necessary to determine conversion factors to enable various kinds of energy to be measured with a uniform yardstick.

The historical energy balances for South Africa were constructed for the period 1910 to 1968. No claim can be made that these energy balances are beyond refinement for it must essentially be seen as the first attempt in this direction. Its effectiveness will only be fully utilised when certain missing data, notably in the conversion sector, are obtained, although it may be a costly operation. Nevertheless, seen in the light of the quality of the final results obtained, it is concluded that these energy balances served their purpose well and established a useful vehicle for forecasting.

In separating the two phases of energy demand, use was made of the traditional input-output table, adapted and tailored to the specific demands of this study. In the sector of final demand, four demand models were constructed, quantifying the demand for energy in each of the households, industrial, mining and transport sub-sectors. The models were applied to forecast final demand, by sector, over three successive forecast

periods, i.e. for 1980, 1990 and 2000 AD.. In terms of the statistical accuracy of these forecasts, as expressed by the width of confidence intervals obtained, it may be concluded that the results are fairly reliable.

When the total final-energy demand has been estimated, the question is from what sources of energy this demand will be met. A complete solution of this problem is not possible by purely quantitative calculations. For a given final-energy demand, the demand for primary energy and its composition depend upon which of the possible ways of meeting the demand have actually been selected at all stages of demand and conversion. A forecast of primary energy requirements can therefore only be made with reasonable reliability by way of backward calculation from the final-energy demand through all conversion processes to the primary-energy stage.

It was established that the forecasting of energy demand is particularly aided by four different methods, viz:

- (i) Direct extrapolation on the basis of observed characteristics of a past trend,
- (ii) Extrapolation from observed past relationships, using economic magnitudes as explanatory or exogenous variables,
- (iii) Forecasts based on planned output in individual economic sectors and the specific energy needs per unit of output,
- (iv) Study of comparative analysis of homologous trends in different countries.

It was found that optimum results are obtained by using all four methods, in combination. More specifically, in the construction of the

sectoral demand models, the second approach, i.e. extrapolating from observed past relationships, was employed. The other methods were found to be useful in determining control forecasts.

On the physical characteristics of the energy economy, it was established that the demand for energy in South Africa has grown rapidly over the past 60 years, realised growth being slightly in excess of experience in other mature Western economies.

Opinions of researchers in the field of energy supply and demand are divided on whether energy demand is a prerequisite of economic growth or the result of it. The view is held that the high rate of growth in demand for energy experienced in South Africa over the last 60 years was the result of interaction between generous local endowment of energy assets, on the one hand, and the combined effect of rapid industrialisation of the domestic economy, and exploitation of the vast mineral wealth of the country, on the other.

The conclusion was made that there is a very close but complex relationship between the demand for energy and general economic growth in South Africa, as elsewhere in the world, that this relationship can be quantified, and that it presents a useful aid to forecasting.

Coal has hitherto provided by far the preponderant part of total energy consumed and has been almost the sole primary source of industrial, mining and domestic energy consumption. This has been due to the vastness and accessibility of local coal resources. These not only number among the largest and cheapest in the world, but are situated on the outskirts of the Reef mining and industrial complex and within reasonable haulage distance of the Free State goldfields and Durban industrial area.

It was also observed that important structural changes are taking

place in the energy economy. The trend is towards more refined, 'noble' and secondary forms of energy, at the expense of coal. The demand for high quality forms of energy follows in the wake of growing technological sophistication. Coal is still the single most important energy-producing agent in the final consumption sector, but is increasingly being challenged by electricity and oil. The rapid growth in the demand for electricity is a world-wide phenomenon and it is predicted that it will be by far the biggest single energy-producing agent by the turn of the century, being more than a third of the total in the final consumption sector. The demand for oil has grown rapidly owing to the high rate of growth experienced in the motor vehicle population of the country and its share of the total final consumption is expected to mount steadily over the next 30 years. The rapid historical increase in the market shares of coke, coke-oven gas and blast-furnace gas reflects the growth and importance of the Republic's metallurgical industries.

Future structural development in the energy economy, regarding resource allocation and pattern of demand, will depend on technological change and structural change in the general economy itself. It is, for instance, predicted that the industrial sector, already the biggest, will further increase its share in the final consumption sector, completely dominating the South African energy economy by the turn of the century. By contrast, the mining sector, once the biggest, will be reduced to the smallest by 2000 AD.

The growth rate in the production of electricity by coal-fired thermal power stations is expected to level off between now and 1980 owing to the combined effect of hydro and nuclear power introduction. During the last decade of the century, absolute thermal production will decline as a result of present indications concerning future nuclear power generation.

It is predicted that the demand for oil will escalate rapidly up to 1980 because of the combined effect of substitution of coal by furnace oil, observed to be taking place in the industrial sector, and projected international bunker demand. These developments imply a requirement for considerable capital investment in petroleum refining facilities during the next few years.

It is evident that future demand for coal, especially between now and 1980, will show only modest increases in view of displacement in progress of coal by oil in the industrial sector and smaller growing offtakes by the electricity generating industry, owing (mainly) to importation of Cabora Bassa hydro electric power. After 1980 the demand for coal will of course also be adversely affected by the advent of nuclear power.

These projected developments in the demand for coal have the effect of extending the life expectancy of South African coal reserves, recently re-assessed, by a number of years. Based on the present demand forecast for coal, the coal reserves of South Africa will probably last for another 84 years, approximately.

6.3. Recommendations

On account of the wide variety of types of energy in use, each calling for different processes of working, including installation, transport and supply facilities, no single agency or organisation deals with the entire field of energy supply. Nevertheless, having regard to the possibility of using different forms of energy for the same process by substitution and conversion, and to the impact of energy on a country's economy as a whole, it is of prime importance that the country formulate and develop

a national energy policy and programmes designed to serve overall and long term needs. Long term programmes should be formulated and implemented before the actual need for them arises.

Energy policy has an important part to play in securing the major economic objectives of steady economic growth, full employment, stability of prices and a satisfactory balance of payments. In this light, the two principal objectives of energy policy can be defined as:

- (i) the assurance of adequate and reasonably secure supplies of the various forms of energy needed to sustain economic growth, and
- (ii) the assurance of reasonable energy prices, and the encouragement of reductions in the cost of energy to the community as a whole and to the individual consumer.

Governments' actions, within the limits set by the size and form of the world's natural resources, are responsible for the overall climate in which the energy sector, both public and private, develops. An adequate supply of energy remains the prime responsibility of the energy industries, but governments have extensive power and a wide range of instruments to influence the developments of the energy sector. It follows that governments are responsible for formulating and implementing a comprehensive and coherent policy. In particular, the need is to replace short-term palliatives by flexible long-term planning and to prevent short-term measures from prejudicing the achievement of long-term objectives.

Each of the branches of the energy industry such as coal, oil, electricity, etc., should organise its own methods of forecasting for its normal operational and development purposes. But there remains the primary mission: providing an overview of the multitude of energy-policy

activities and acting as a catalyst to see that they work in reasonable harmony to achieve the goal of plentiful and secure supplies of energy at low cost. The forecasts by individual energy industries should be co-ordinated into a national comprehensive forecast by a central planning agency in the country or by a ministry or department designated for the purpose. It may also be necessary to take recourse to assistance from consultative or advisory committees comprising members with specialised experience in the different fields.

It is not suggested that there should be any rigid uniformity in the type of energy forecasting and planning organisation. While it will depend on a combination of circumstances, it is most desirable to ensure that the overall responsibility for working out comprehensive plans and projections covering all the main sectors of energy supply is effectively exercised.

This overall responsibility for co-ordination can be exercised in the following alternative ways:

- (i) By establishing a central authority for energy planning.
- (ii) By establishing or designating a ministry to undertake the co-ordinated study of basic power and energy policy.
- (iii) By setting up expert consultative or advisory committees comprising representatives of interested ministries, and supply and consumer interests.
- (iv) By utilizing the forecasting services of main supply sectors where these are comprehensive and well established, supplemented by ad hoc investigations by specially appointed consultants from time to time.

It must be realised that the availability and cost of the various forms of energy in a given region have a marked influence on the development of that region. It is therefore imperative that the future development of the country be related to the availability and cost of the various forms of energy. No country can afford to penalise its competitive standing by adding unnecessarily to its energy costs. Accordingly, it should be the Government's aim to shape developments in the energy sector in order to bring the greatest strength to the economy.

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APPENDIX I

SECTORAL BREAKDOWN OF OIL DEMAND

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1910

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	23						23
ILLUMINATING PARAFFIN		216					216
POWER PARAFFIN							
LIGHT DIESEL							
HEAVY DIESEL					2		2
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	23	216			2		241

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1911

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	34						34
ILLUMINATING PARAFFIN		227					227
POWER PARAFFIN							
LIGHT DIESEL							
HEAVY DIESEL					2		2
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	34	227			2		263

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1912

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	54						54
ILLUMINATING PARAFFIN		251					251
POWER PARAFFIN							
LIGHT DIESEL							
HEAVY DIESEL					2		2
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	54	251			2		307

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1913

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	112						112
ILLUMINATING PARAFFIN		279					279
POWER PARAFFIN							
LIGHT DIESEL							
HEAVY DIESEL					3		3
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	112	279			3		394

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1914

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	109						109
ILLUMINATING PARAFFIN		285					285
POWER PARAFFIN							
LIGHT DIESEL					2		2
HEAVY DIESEL					3		3
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	109	285			5		399

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1915

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	128						128
ILLUMINATING PARAFFIN		265					265
POWER PARAFFIN							
LIGHT DIESEL					4		4
HEAVY DIESEL					3		3
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	128	265			7		400

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1916

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	142						142
ILLUMINATING PARAFFIN		266					266
POWER PARAFFIN							
LIGHT DIESEL					22		22
HEAVY DIESEL			2		19		21
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	142	266	2		41		451

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1917

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	176						176
ILLUMINATING PARAFFIN		259					259
POWER PARAFFIN							
LIGHT DIESEL					30		30
HEAVY DIESEL			3		27		30
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	176	259	3		57		495

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1918

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	140						140
ILLUMINATING PARAFFIN		154					154
POWER PARAFFIN							
LIGHT DIESEL					40		40
HEAVY DIESEL			4		36		40
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE							
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	140	154	4		76		374

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1919

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	195						195
ILLUMINATING PARAFFIN		190					190
POWER PARAFFIN							
LIGHT DIESEL					46		46
HEAVY DIESEL			5		41		46
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE	3						3
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	198	190	5		87		480

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1920

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	278						278
ILLUMINATING PARAFFIN		221					221
POWER PARAFFIN							
LIGHT DIESEL			5		50		55
HEAVY DIESEL			5		49		54
LIGHT FURNACE OIL							
HEAVY FURNACE OIL							
AVIATION GASOLINE	6						6
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	284	221	10		99		614

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1921

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	286						286
ILLUMINATING PARAFFIN		216					216
POWER PARAFFIN							
LIGHT DIESEL			8		52		60
HEAVY DIESEL			6		53		59
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	5						5
AVIATION GASOLINE	9						9
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	300	216	14		105		635

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1922

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	270						270
ILLUMINATING PARAFFIN		237					237
POWER PARAFFIN							
LIGHT DIESEL			10		54		64
HEAVY DIESEL			6		58		64
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	10						10
AVIATION GASOLINE	12						12
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	292	237	16		112		657

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1923

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	366						366
ILLUMINATING PARAFFIN		208					208
POWER PARAFFIN							
LIGHT DIESEL			14		56		70
HEAVY DIESEL			7		63		70
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	15						15
AVIATION GASOLINE	15						15
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	396	208	21		119		744

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1924

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	476						476
ILLUMINATING PARAFFIN		260					260
POWER PARAFFIN		10					10
LIGHT DIESEL			17		58		75
HEAVY DIESEL			8		67		75
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	20						20
AVIATION GASOLINE	18						18
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	514	270	25		125		934

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1925

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	528						528
ILLUMINATING PARAFFIN		262					262
POWER PARAFFIN		20					20
LIGHT DIESEL			21		60		81
HEAVY DIESEL			8		72		80
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	25						25
AVIATION GASOLINE	21						21
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	574	282	29		132		1017

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1926

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	859						859
ILLUMINATING PARAFFIN		262					262
POWER PARAFFIN		20					20
LIGHT DIESEL			26		62		88
HEAVY DIESEL			9		79		88
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	30						30
AVIATION GASOLINE	24						24
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	913	282	35		141		1371

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1927

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	955						955
ILLUMINATING PARAFFIN		246					246
POWER PARAFFIN		40					40
LIGHT DIESEL			45		64		109
HEAVY DIESEL			11		98		109
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	35						35
AVIATION GASOLINE	27						27
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	1017	286	56		162		1521

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1928

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	1240						1240
ILLUMINATING PARAFFIN		303					303
POWER PARAFFIN		60					60
LIGHT DIESEL	5		59		66		130
HEAVY DIESEL			13		117		130
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	35						35
AVIATION GASOLINE	30						30
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	1310	363	72		183		1928

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1929

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	1759						1759
ILLUMINATING PARAFFIN		408					408
POWER PARAFFIN		100					100
LIGHT DIESEL	10		73		68		151
HEAVY DIESEL			15		136		151
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	40						40
AVIATION GASOLINE	33						33
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	1842	508	88		204		2642

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1930

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	1642						1642
ILLUMINATING PARAFFIN		322					322
POWER PARAFFIN		121					121
LIGHT DIESEL	20		81		70		171
HEAVY DIESEL			17		153		170
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	45						45
AVIATION GASOLINE	36						36
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	1743	443	98		223		2507

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1931

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	1691						1691
ILLUMINATING PARAFFIN		265					265
POWER PARAFFIN		55					55
LIGHT DIESEL	30		87		74		191
HEAVY DIESEL			19		171		190
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	50						50
AVIATION GASOLINE	39						39
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	1810	320	106		245		2481

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1932

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	1680						1680
ILLUMINATING PARAFFIN		283					283
POWER PARAFFIN		88					88
LIGHT DIESEL	40		92		80		212
HEAVY DIESEL			21		190		211
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	55						55
AVIATION GASOLINE	42						42
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	1817	371	113		270		2571

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1933

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	1900						1900
ILLUMINATING PARAFFIN		312					312
POWER PARAFFIN		93					93
LIGHT DIESEL	50		94		86		230
HEAVY DIESEL			23		207		230
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	60						60
AVIATION GASOLINE	45						45
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	2055	405	117		293		2870

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1934

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	2199						2199
ILLUMINATING PARAFFIN		388					388
POWER PARAFFIN		189					189
LIGHT DIESEL	60		97		93		250
HEAVY DIESEL			25		224		249
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	65						65
AVIATION GASOLINE	48						48
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	2372	577	122		317		3388

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1935

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	2609						2609
ILLUMINATING PARAFFIN		355					355
POWER PARAFFIN		126					126
LIGHT DIESEL	70	2	96	2	100		270
HEAVY DIESEL			27		242		269
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	70						70
AVIATION GASOLINE	51						51
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	2800	483	123	2	342		3750

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1936

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	3228						3228
ILLUMINATING PARAFFIN		385					385
POWER PARAFFIN		166					166
LIGHT DIESEL	80	6	88	6	108		288
HEAVY DIESEL			29		259		288
LIGHT FURNACE OIL							
HEAVY FURNACE OIL	80						80
AVIATION GASOLINE	54						54
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	3442	557	117	6	367		4489

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1937

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	4022						4022
ILLUMINATING PARAFFIN		457					457
POWER PARAFFIN		162					162
LIGHT DIESEL	92	10	79	8	116		305
HEAVY DIESEL			31		274		305
LIGHT FURNACE OIL			5				5
HEAVY FURNACE OIL	90						90
AVIATION GASOLINE	57						57
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	4261	629	115	8	390		5403

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1938

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	4534						4534
ILLUMINATING PARAFFIN		439					439
POWER PARAFFIN		186					186
LIGHT DIESEL	114	14	56	10	125		319
HEAVY DIESEL			32		287		319
LIGHT FURNACE OIL			10				10
HEAVY FURNACE OIL	100						100
AVIATION GASOLINE	59						59
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	4807	639	98	10	412		5966

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1939

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	4849						4849
ILLUMINATING PARAFFIN		550					550
POWER PARAFFIN		321					321
LIGHT DIESEL	133	12	50	11	148		354
HEAVY DIESEL			35		315		350
LIGHT FURNACE OIL			15				15
HEAVY FURNACE OIL	95						95
AVIATION GASOLINE	61						61
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	5138	883	100	11	463		6595

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1940

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	4869						4869
ILLUMINATING PARAFFIN		491					491
POWER PARAFFIN		292					292
LIGHT DIESEL	81	12	32	11	158		294
HEAVY DIESEL			31		288		319
LIGHT FURNACE OIL			20				20
HEAVY FURNACE OIL	75						75
AVIATION GASOLINE	104						104
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	5129	795	83	11	446		6464

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1941

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	4981						4981
ILLUMINATING PARAFFIN		553					553
POWER PARAFFIN		342					342
LIGHT DIESEL	65	11	25	11	169		281
HEAVY DIESEL			34		302		336
LIGHT FURNACE OIL			25				25
HEAVY FURNACE OIL	60						60
AVIATION GASOLINE	201						201
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	5307	906	84	11	471		6779

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1942

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	4057						4057
ILLUMINATING PARAFFIN		873					873
POWER PARAFFIN		373					373
LIGHT DIESEL	60	11	22	11	181		285
HEAVY DIESEL			35		311		346
LIGHT FURNACE OIL			30				30
HEAVY FURNACE OIL	30						30
AVIATION GASOLINE	560						560
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	4707	1257	87	11	492		6554

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1943

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	3598						3598
ILLUMINATING PARAFFIN		603					603
POWER PARAFFIN		420					420
LIGHT DIESEL	43	10	20	12	194		279
HEAVY DIESEL			32		286		318
LIGHT FURNACE OIL			35				35
HEAVY FURNACE OIL	16						16
AVIATION GASOLINE	682						682
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	4339	1033	87	12	480		5951

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1944

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	3591						3591
ILLUMINATING PARAFFIN		655					655
POWER PARAFFIN		497					497
LIGHT DIESEL	42	11	21	13	208		295
HEAVY DIESEL			34		301		335
LIGHT FURNACE OIL			40				40
HEAVY FURNACE OIL	20						20
AVIATION GASOLINE	704						704
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	4357	1163	95	13	509		6137

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1945

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	3834						3834
ILLUMINATING PARAFFIN		676					676
POWER PARAFFIN		589					589
LIGHT DIESEL	50	20	21	14	225		330
HEAVY DIESEL			33		295		328
LIGHT FURNACE OIL			45				45
HEAVY FURNACE OIL	30						30
AVIATION GASOLINE	317						317
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	4231	1285	99	14	520		6149

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1946

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	5537						5537
ILLUMINATING PARAFFIN		760					760
POWER PARAFFIN		794					794
LIGHT DIESEL	93	22	31	25	240		411
HEAVY DIESEL			34		309		343
LIGHT FURNACE OIL			50				50
HEAVY FURNACE OIL	50						50
AVIATION GASOLINE	100						100
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	5780	1576	115	25	549		8045

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1947

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	6731						6731
ILLUMINATING PARAFFIN		834					834
POWER PARAFFIN		933					933
LIGHT DIESEL	120	35	95	55	259		564
HEAVY DIESEL			37		333		370
LIGHT FURNACE OIL			55				55
HEAVY FURNACE OIL	60						60
AVIATION GASOLINE	132						132
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	7043	1802	187	55	592		9679

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1948

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	7861						7861
ILLUMINATING PARAFFIN		952					952
POWER PARAFFIN		1114					1114
LIGHT DIESEL	144	45	170	95	279		733
HEAVY DIESEL			42		376		418
LIGHT FURNACE OIL			60				60
HEAVY FURNACE OIL	70						70
AVIATION GASOLINE	165						165
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	8240	2111	272	95	655		11373

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1949

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	8751						8751
ILLUMINATING PARAFFIN		1031					1031
POWER PARAFFIN		1414					1414
LIGHT DIESEL	235	100	215	135	300		985
HEAVY DIESEL			43		387		430
LIGHT FURNACE OIL			70				70
HEAVY FURNACE OIL	80						80
AVIATION GASOLINE	185						185
JET FUEL							
LIQUEFIED PETROLEUM GAS							
T O T A L	9251	2545	328	135	687		12946

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1950

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	8839						8839
ILLUMINATING PARAFFIN		1054					1054
POWER PARAFFIN		1603					1603
LIGHT DIESEL	293	146	270	171	321		1201
HEAVY DIESEL			34		308		342
LIGHT FURNACE OIL			95				95
HEAVY FURNACE OIL	64						64
AVIATION GASOLINE	201						201
JET FUEL	5						5
LIQUEFIED PETROLEUM GAS							
T O T A L	9402	2803	399	171	629		13404

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1952

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	9917						9917
ILLUMINATING PARAFFIN		1136					1136
POWER PARAFFIN		2138					2138
LIGHT DIESEL	394	364	330	192	332		1612
HEAVY DIESEL			27		242		269
LIGHT FURNACE OIL			112				112
HEAVY FURNACE OIL	40						40
AVIATION GASOLINE	206						206
JET FUEL	16						16
LIQUEFIED PETROLEUM GAS							
T O T A L	10573	3638	469	192	574		15446

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1953

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	10291						10291
ILLUMINATING PARAFFIN		1210					1210
POWER PARAFFIN		2414					2414
LIGHT DIESEL	462	476	360	204	434		1936
HEAVY DIESEL			22		199		221
LIGHT FURNACE OIL			142				142
HEAVY FURNACE OIL	42						42
AVIATION GASOLINE	211						211
JET FUEL	30						30
LIQUEFIED PETROLEUM GAS							
T O T A L	11036	4100	524	204	633		16497

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1954

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	10673						10673
ILLUMINATING PARAFFIN		1311					1311
POWER PARAFFIN		2611					2611
LIGHT DIESEL	546	599	390	217	604		2356
HEAVY DIESEL			23		210		233
LIGHT FURNACE OIL			162				162
HEAVY FURNACE OIL	46						46
AVIATION GASOLINE	227						227
JET FUEL	21						21
LIQUEFIED PETROLEUM GAS							
T O T A L	11513	4521	575	217	814		17640

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1955

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	11366						11366
ILLUMINATING PARAFFIN		1384					1384
POWER PARAFFIN		2579					2579
LIGHT DIESEL	723	737	420	231	818		2929
HEAVY DIESEL			19		169		188
LIGHT FURNACE OIL			171				171
HEAVY FURNACE OIL	68						68
AVIATION GASOLINE	236						236
JET FUEL	25						25
LIQUEFIED PETROLEUM GAS							
T O T A L	12418	4700	610	231	987		18946

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1956

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	11843						11843
ILLUMINATING PARAFFIN		1461					1461
POWER PARAFFIN		2614	4				2618
LIGHT DIESEL	993	873	450	246	973		3535
HEAVY DIESEL			14		129		143
LIGHT FURNACE OIL			177				177
HEAVY FURNACE OIL	67						67
AVIATION GASOLINE	269						269
JET FUEL	38						38
LIQUEFIED PETROLEUM GAS			6				6
T O T A L	13210	4948	651	246	1102		20157

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1957

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	12445						12445
ILLUMINATING PARAFFIN		1493					1493
POWER PARAFFIN		2596	10				2606
LIGHT DIESEL	1430	1070	480	261	762		4003
HEAVY DIESEL			9		85		94
LIGHT FURNACE OIL			241				241
HEAVY FURNACE OIL	63						63
AVIATION GASOLINE	282						282
JET FUEL	65						65
LIQUEFIED PETROLEUM GAS			30				30
T O T A L	14285	5159	770	261	847		21322

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1958

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	13052						13052
ILLUMINATING PARAFFIN		1552					1552
POWER PARAFFIN		2416	20				2436
LIGHT DIESEL	1917	1357	510	278	547		4609
HEAVY DIESEL	2		9		81		92
LIGHT FURNACE OIL			294				294
HEAVY FURNACE OIL	213		7				220
AVIATION GASOLINE	290						290
JET FUEL	59						59
LIQUEFIED PETROLEUM GAS		5	44				49
T O T A L	15533	5330	884	278	628		22653

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1959

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	13419						13419
ILLUMINATING PARAFFIN		1600					1600
POWER PARAFFIN		2358	30				2388
LIGHT DIESEL	2130	1628	546	296	393		4993
HEAVY DIESEL	9		10		76		95
LIGHT FURNACE OIL			280				280
HEAVY FURNACE OIL	227		9				236
AVIATION GASOLINE	194						194
JET FUEL	205						205
LIQUEFIED PETROLEUM GAS		15	65				80
T O T A L	16184	5601	940	296	469		23490

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1960

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	13955						13955
ILLUMINATING PARAFFIN		1650					1650
POWER PARAFFIN		2291	40				2331
LIGHT DIESEL	2372	1882	591	315	448		5608
HEAVY DIESEL	1		7		62		70
LIGHT FURNACE OIL			252				252
HEAVY FURNACE OIL	265		25				290
AVIATION GASOLINE	205						205
JET FUEL	299						299
LIQUEFIED PETROLEUM GAS		34	72				106
T O T A L	17097	5857	987	315	510		24766

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1961

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	14310						14310
ILLUMINATING PARAFFIN		1703					1703
POWER PARAFFIN		2170	50				2220
LIGHT DIESEL	2644	2182	656	336	311		6129
HEAVY DIESEL	3		6		47		56
LIGHT FURNACE OIL			281				281
HEAVY FURNACE OIL	293		92				385
AVIATION GASOLINE	219						219
JET FUEL	383						383
LIQUEFIED PETROLEUM GAS		54	95				149
T O T A L	17852	6109	1180	336	358		25835

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1962

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	14734						14734
ILLUMINATING PARAFFIN		1783					1783
POWER PARAFFIN		2017	107				2124
LIGHT DIESEL	2943	2396	741	359	373		6822
HEAVY DIESEL	5		2		14		21
LIGHT FURNACE OIL			336				336
HEAVY FURNACE OIL	320		133				453
AVIATION GASOLINE	228						228
JET FUEL	433						433
LIQUEFIED PETROLEUM GAS		79	130				209
T O T A L	18673	6275	1449	359	387		27143

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1963

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	15543						15543
ILLUMINATING PARAFFIN		1875					1875
POWER PARAFFIN		1826	190				2016
LIGHT DIESEL	3353	2802	861	383	184		7583
HEAVY DIESEL	5		3		20		28
LIGHT FURNACE OIL			347				347
HEAVY FURNACE OIL	345		343				688
AVIATION GASOLINE	221						221
JET FUEL	510						510
LIQUEFIED PETROLEUM GAS		119	180				299
T O T A L	19977	6622	1924	383	204		29110

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1964

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	17031						17031
ILLUMINATING PARAFFIN		1946					1946
POWER PARAFFIN		1632	280				1912
LIGHT DIESEL	3885	3134	1027	409	292		8747
HEAVY DIESEL	11		3		13		27
LIGHT FURNACE OIL			355				355
HEAVY FURNACE OIL	332		458				790
AVIATION GASOLINE	262						262
JET FUEL	564						564
LIQUEFIED PETROLEUM GAS		158	228				386
T O T A L	22085	6870	2351	409	305		32020

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1965

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	18501						18501
ILLUMINATING PARAFFIN		2072					2072
POWER PARAFFIN		1470	370				1840
LIGHT DIESEL	4555	3478	1220	437	491		10181
HEAVY DIESEL	17		4		20		41
LIGHT FURNACE OIL			350				350
HEAVY FURNACE OIL	396		780				1176
AVIATION GASOLINE	242						242
JET FUEL	751						751
LIQUEFIED PETROLEUM GAS		206	287				493
T O T A L	24462	7226	3011	437	511		35647

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1966

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	19763						19763
ILLUMINATING PARAFFIN		2211					2211
POWER PARAFFIN		1097	660				1757
LIGHT DIESEL	5400	3768	1378	467	245		11258
HEAVY DIESEL	32		7		30		69
LIGHT FURNACE OIL			351				351
HEAVY FURNACE OIL	464		1335				1799
AVIATION GASOLINE	217						217
JET FUEL	1068						1068
LIQUEFIED PETROLEUM GAS		251	328				579
T O T A L	26944	7327	4059	467	275		39072

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1967

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	20896						20896
ILLUMINATING PARAFFIN		2310					2310
POWER PARAFFIN		958	666				1624
LIGHT DIESEL	6249	4097	1564	499	208		12617
HEAVY DIESEL	54		11		43		108
LIGHT FURNACE OIL			355				355
HEAVY FURNACE OIL	416		1967			29	2412
AVIATION GASOLINE	232						232
JET FUEL	1188						1188
LIQUEFIED PETROLEUM GAS		315	323				638
T O T A L	29035	7680	4886	499	251	29	42380

INLAND OIL CONSUMPTION BY SECTOR, REPUBLIC OF SOUTH AFRICA AND SOUTH WEST AFRICA

1968

'000 BARRELS	TRANSPORT	HOUSEHOLDS	INDUSTRY	MINING	ELECTRICITY GENERATION	GAS PRODUCTION	TOTAL
PETROL	22505						22505
ILLUMINATING PARAFFIN		2393					2393
POWER PARAFFIN		841	644				1485
LIGHT DIESEL	7233	4329	1750	538	130		13980
HEAVY DIESEL	63		11		37		111
LIGHT FURNACE OIL			323				323
HEAVY FURNACE OIL	234		2432			57	2723
AVIATION GASOLINE	212						212
JET FUEL	1362						1362
LIQUEFIED PETROLEUM GAS		370	382				752
T O T A L	31609	7933	5542	538	167	57	45846

APPENDIX II

SUMMARY OF SOME MAIN TYPES OF STATISTICAL
PROJECTION USED IN ENERGY FORECASTING

A. Types of Formula used in Direct Extrapolation

There is no generally valid principle or absolute test to decide which type of expression best corresponds to a given trend in a series of data. Judgment and experience must play an important part in the selection of an appropriate formula.

It may be recalled that, in their natural form, the more common types of expression involved may be characterised as follows:

Exponential type:

With values of x forming an arithmetic series, the corresponding y values give a geometric series, so that:

$$y = ab^x$$

Modified exponential type:

With values of x forming an arithmetic series, the corresponding y values depart from a geometric series by a constant magnitude, so that:

$$y = ab^x - M$$

Parabolic or hyperbolic type:

With values of x forming a geometric series, the corresponding y values form a geometric series, so that:

$$y = ax^b$$

Straight line type:

With values of x forming an arithmetic series, the first order differences of the corresponding y values are constant, so that:

$$y = a + bx$$

Polynomial types:

With the values of x arranged in an arithmetic series, the n th differences of the corresponding y values are constant, so that:

$$y = a + b x + c x^2 + d x^3 + \dots + px^n$$

The following additional formulae of common application, but characterising a more complex growth process, may be set out in a similar form:

Law of growth type:

For an expression conforming to a law of growth characteristic of population increase, one has the type giving the Gompertz curve:

$$y = ab^{c^x}$$

Logistic type:

For a modified geometrical series also used originally in population studies, with similar basic characteristics to the trend characterised by the Gompertz curve, one has the corresponding elements of the logistic type¹⁾:

1) From this follows the familiar form of the logistic expression, ie.;

$$y = \frac{1}{a + be^{-x}}$$

$$\frac{1}{y} = a + bc^x$$

For methods of applying these types of formula in practice reference may be made to Croxton and Cowden.^{84/}

For the analysis of future electric power requirements, especially, many types of expression, constituting variants of the basic types set out above or related empirical formulae, can be used. These include cubic, quadratic, hyperbolic and other modified types of exponential formulae, plus Gompertz, logistic and other variants.^{78/14/85/86/87/}

B. Types of Formula used in Extrapolation of Relationships and in Explanatory Models

(i) Relationships with an index of economic activity

If the relationships between forms of energy and indices of economic activity are taken to be of linear form, they may still be expressed in various ways, i.e. in linear or logarithmic coordinates, as indices relative to a base-year as 100, or as absolute values, specific values, rates of change, etc. They may equally express simple or multiple relationships. Alternatively, instead of selecting the variables x and y of the normal linear regression equation ($E = ax + by + c$) from a priori considerations, it is possible to test a number of such expressions, using different variables, and to select that which gives the closest correlation and of which the coefficients (a and b) appear the most appropriate.

In the form of an index of energy consumption, one may extend the direct extrapolation as a function of time in a form developed by Electricité de France,^{78/} i.e. by taking account of change in an index

of economic activity "P".

Thus, if E_n is the index of consumption required in year n (E_0 is taken as 100) and "a" is a regression coefficient related to time, then:

$$E_n = E_0 (1 + a)^n$$

If one allows for both the elasticity (b) relative to the economic activity, P, and for an extension to new applications of the form of energy (a') then the formula becomes:

$$E_n = E_0 (1 + a')^n \left(\frac{P_n}{P_0} \right)^b$$

This kind of expression may be treated in such a way as to express the degree of probability of the level E_n being reached in the period n from the starting point E_0 .^{78/}

(ii) Relationships based on exponential increase in output and specific energy consumption per unit of output

Here the method of the central economic plan is defined in its simplest form, where:

$$E = s_0 P_0^b e^{rt}$$

s_0 = the specific consumption in the base-year corresponding to output P_0

b = a coefficient which takes account of any special factors influencing development of consumption

r = the percentage rate of increase in output and

t = time

A series of more detailed expressions for changes in energy requirements based on output and specific consumption can be derived to take account of conditions in different industries, installation of new equipment, etc.^{78/}