SOME ECONOMIC CONSIDERATIONS IN ELECTRICITY PRODUCTION IN NIGERIA.

By S. A. ONYEWUENYI, A.M.I.E.C., A.M.N.S.E

1. INTRODUCTION

In the world today, the orderly economic development of a country is dependent upon the existence of certain fundamental services. These include adequate road and transport systems and port facilities, reasonable facilities for intercommunication — internally by telephone or telegrah and externally by wireless and cable —, and an adequate supply of cheap electrical energy.

Electric power plays an important role in the development of any country Modern civilisation calls for increased use of numerous electrical domestic appliances and labour saving devices both in the home and in the office. Rapid industrialisation becomcs possible when cheap electric power is available. It has, in fact, been said that the standard of living in a country depends to a certain extent, on its consumption of electricity.

In order to play its role of raising the standard of living effectively, electricity supply must be adequate and cheap enough to encourage its continued and increased use by a large percentage of the population. More important still, it must be reliable since modern industrial techniques and service involve complicated processes, high precision and split second control. Constant failure of electricity supply, apart from the incovenience caused, can result in the loss of large sums of money by industry as well as disorganise essential services like telecommunication, water supply transport etc.

It is said that electricity demanded forms over one-fifth of world energy demand. The annual consumption of electricity is increasing very rapidly and is said to be developing at a faster rate than that of all forms of energy as a whole. This is most probably due to the fact that it meets the two basic human needs for energy and for improvement of the standard of living — HEAT AND MOTIVE POWER. One can hardly over-emphasize the significance and importance attached to man's discovery of FIRE and the invention of the WHEEL.

In the more developed countries there has been a tendency for electricity demand to double every ten years. This gives an average annual increase of 7% to 8%. In Nigeria, since the formation of the Electricity Corporation of Nigeria (E.C.N.) in 1951, electricity demand has increased at an average rate of 21% per annum, i.e. a doubling in demand every four to five years. A very heavy programme of electricity expansion is, therefore, necessary to keep pace with such rapid growth in demand and this calls for capital investment on a large scale.

Figure 1 shows the sale of electricity by the Electricity Corporation of Nigeria for the ten year period — 1953 to 1962.

2. Resources for Electric Power Production

Electric power is what is termed secondary energy and is normally produced from primary energy resources. All countries are trying to make the best use of the resources available in order to produce electric power as cheaply as possible.

The main energy resources employed in the production of electric power in Nigeria are hydro, coal, and natural gas, the last three being known as conventional types of fuel. There are, of course, other sources of energy for production of elec-

tricity, e.g. wind, sea tides and solar energy. These have, however, not been developed for large scale or commercial use by Public Utility Authorities and have, therefore, not yet entered the Nigerian scene.

Another important source is atomic power. Although this source is now being utilised in atomic power stations for commercial operation, it has not been introduced into this country. There are, however, certain features of atomic power plant which will preclude its use in Nigeria at least for the next decade. For example, its high initial cost — about double that for steam plant. This limits the economic size of plant to not less than 150 M.W. Atomic power plants are not suitable for variable load operation due to the difficulty in achieving quick control over their operation. They are, therefore, only useful as base load stations operating at load factors of not less than about 80%. Added to these, of course, is the problem of disposal of radio-active waste products.

2.2. Availability of resources in Nigeria

Nigeria is blessed with abundance of energy resources. Practically all the important energy resources utilised for the production of electricity the world over are available in the country. Coal is located near Enugu in the Eastern Region and extends into the Northern Region. The total reserve is estimated at 350 million tons and is at present being extracted from underground mines at the rate of about 600,000 tons per annum. The net calorific value has been quoted variously at between 8,000 and 12,200 B.T.U/Lb. For several years coal was the only significant commercial fuel used in Nigeria for power production but by the end of 1963 electric power production from coal had dwindled to a little over 17.8% of the total (see Table 1).

Lignite deposits are known to exist in substantial quantities near the Niger River delta and extending northwards on either side of the River. Definite deposits estimated at some 60 million tons have been mapped out in the Asaba—Ogwashi vicinity. Although there were plans in the early years of the Electricity Corporation of Nigeria to utilise the lignite deposits of Asaba for power generation, there is no record of any commercial production of lignite in Nigeria.

Oil and natural gas have been discovered in considerable quantities and Nigeria is now an exporter of crude oil. Production of crude oil started around 1958 and, since then,has risen from about 2 million barrels in that year to well over 17 million barrels in 1962. Up till now all fuel oil used for electricity production has been imported. It is, however, hoped that by the end of 1965 it will be possible to supply most of the country's requirements in this respect from the Refinery now being built at Alese-Eleme near Okrika. Electric power production from oil accounted for well over 60% of the total in 1963.

Natural gas occurs either associated with oil or 'non-associated'. Reserves are said to be substantial although no reliable figure has been given. In 1963 this source accounted for only 7.15% of total electric power production. It is, however, expected that by 1967 its contribution will be considerably higher than this. The calorific value is around 950 B.T.U/cu.ft.

The hydro-electric resources which have been investigated are located mainly in Northern Nigeria. In the past, production of electric power from hydro sources has been limited to the Jos Plateau area. The estimated total hydro-electric potential of Nigeria is not known but the integrated Niger/Shiroro scheme is expected to provide a firm capacity of about 1,940 MW., at 55% load factor, in three stages

(Kainji 960 MW; Jebba 500 MW; Shiroro 480 MW).

So far no appreciable discovery of radioactive material has been reported in Nigeria. We cannot therefore be sure that we possess any source of atomic energy.

TABLE 1

ELECTRICITY PRODUCTION IN NIGERIA

BY TYPES OF ENERGY SOURCE — 1963/64

Primary Energy Source.	PRODUCTION OF ELECTRICITY (106 KWH)	
	Total Electric Energy By Public Supply Authority.	%
Enugu Coal	160.9×10^6 KWH.	17. 8
Oil	557.2×10^6 "	61. 7
Natural Gas	64.6×10^6 "	7.15
Total Thermal	782.7×10^6 KWH.	86.65
Water Power	121.2 x 106*	13.35
Total All Sources	903.9 x 106	100. 0

*** Nigerian Electricity Supply Corporation.**

3. Types of Plant

(1)1 Steam Plant

There are two types of steam plant used for electricity production :-

(*i*) Condensing type steam turbo-generator plants.

(*ii*) Non-condensing or back pressure turbine plants.

The condensing type of plant employs a condenser to reconvert the steam to water after it has passed through the turbine. The plants are usually of large size and fuel used is mainly coal or oil. The cost of power generation per kilowatt-hour is lower at high load factors. Also the efficiency of the plant increases, to a certain extent, with size, and for this reason plants of up to 550 MW capacity, in one unit, are now being made. This type of plant is suitable for base load operation.

Non-condensing plants employ back-pressure turbines and are used for power generation when exhaust steam can be used for industrial application or for heating purposes.

The bulk of steam plant employed for power generation in Nigeria is of the condensing type, the largest single unit in operation at this time being of 30 MW capacity.

(2) Diesel-Electric Plants

Diesel Electric plants have been used mainly for small stations where they can

be run as base load plant, or as supplementary or peak lopping plants in conjunction with hydro or steam plant. The diesel-electric plant is very suitable for small and medium output power stations for the following reasons :-

(*a*) It can be quickly started and put on load.
(*b*) There are no standby or banking losses.
(*c*) It has high operating efficiency which bears no relation to output.
(*d*) The plant layout is usually simple resulting in reduced space and cost of buildings.
(*e*) It has limited cooling water supply requirements.
(*f*) Easier handling of fuel, smaller storage space for fuel, and no refuse to dispose of.

Disadvantages are :-

(*a*) Fuel may have to be obtained from abroad.
(*b*) Comparatively high plant cost per kilowatt installed.
(*c*) Plant floor area and costs increase in proportion to increase of capacity and generally fix economic limit at 15 MW.

Diesel-electric installations can be arranged for automatic starting especially when intended for use as stand-by plants to large steam turbine plants or hydro-electric plants, having to be started up immediately on failure of supply.

(3) Gas Turbine Plants

Gas turbine plants in some situations are the cheapest form of emergency, intermittent or peak load plant for use in combination with base load plants in the system. Gas turbines are most likely to be used for power generation where oil fuel is cheap or where natural gas is available; where water source is scarce or the load factor is low. The thermal efficiencies are usually low ranging from 15% to 25%. Some of the special features of gas turbine plant are :-

(*a*) Mechanically, it is simpler than steam or Diesel-electric plants and requires fewer attendants for operation. Also space requirement is small.
(*b*) The capital cost is comparatively low.
(*c*) It requires little or no attendance at standstill and consequently no standby losses. It has short starting and loading time.
(*d*) It has low fuel consumption during starting up and shutting down periods.
(*e*) Circulating water requirements are low and, provided oil fuel or natural gas is economically available, the plant can be located in cities and industrial centres in close proximity to the load centres. The disadvantage here is the high frequency noise emanating from the compressor intake which is likely to be objectionable.
(*f*) The plant does not require very heavy foundations and needs less construction time than steam plant.

The size of gas turbine plant used in Nigeria at present vary from 5 MW to 17.5 MW. The New installation planned in the Delta area will consist initially of two units each of 36 MW capacity.

(4) Hydro-Electric Plant

Hydro-Electric schemes are classified into two broad types :-

(*i*) Schemes depending primarily on flow.
(*ii*) Schemes depending primarily on storage.

The former includes most run of river types where the pondage is usually small.

Power generation takes place during the period of the year when enough quantity of water is available at a high head.

The latter type includes schemes employing dams to store water. The effect of storage is to either increase the effective head or the quantity of water, or both. The storage may be large or small.

Hydro-stations are increasing in size and units up to 300 MW capacity have been made. The efficiency is about 85%. The place of hydro-stations, especially the large storage types, is as base load stations. Certain schemes are, however, suitable for peak lopping e.g. pump storage schemes or schemes with small storage. As already indicated hydro-electric plants can be used to supply all the load requirements of a power system if enough capacity is available. However, it has been found that association with thermal and other types of plants makes the cost of electric power generation more economical.

Up till now hydro-electric power has been produced on the Plateau only by the N.E.S.Co. The total installed capacity at end of 1963 was about 21,000 kW. However, the first stage of the Niger Dam Scheme at Kainji which is now expected to be in operation before the end of 1968, will consist of 4 x 80 MW. Turbine-generator units giving a total output capacity of about 320 MW. The ultimate capacity of the Kainji scheme is expected to be twelve 80 MW units or a total capacity of 960 MW.

Table 2 shows the installed capacities of the various types of electric generating plant operating in Nigeria.

TABLE 2

INSTALLED CAPACITIES (PUBLIC ELECTRICITY SUPPLY)

TYPE OF PLANT	INSTALLED CAPACITY (KW)	
	1959/60	1964/65
STEAM	95,050	141,550
DIESEL	38,500	58,098
[B]GAS TURBINE	—	26,560
TOTAL THERMAL	133,550	226,208
HYDRO PLANT	—	—
TOTAL (ALL PLANT)	133,550	226,208

B Includes 6 M.W. of Free Piston Gas Turbine installation at Challowa, near Kano.

4. Capital Requirements

The Electricity Supply Industry is one of the most intensive capital consumers of all industries. This is true in Nigeria as in other parts of the world. In Nigeria

the tendency is further pronounced by the very high rate of growth of the demand for electricity and the fact that practically all the necessary equipment for generation and distribution is imported.

A large percentage of the capital expenditure is incurred on power station plant and buildings, transmission and distribution lines and substations. Typical plant costs are given in Tables 3a, b and c below for the three most commonly used types of plant employed at the present time in the public sector of electric power production.

TABLE 3

CAPITAL COST OF TYPICAL PLANT

3(*a*) *Steam Plant*

Total Installed Capacity (KW)	Total Capital Cost (£)	Cost per KW (£)
85,000	7,110,000	85
30,000	3,363,000	116
4,800	625,000	139

3(*b*) *Gas Turbine Plant.*

Total Installed Capacity (KW)	Total Capital Cost (£)	Cost per KW (£)
72,000	4,500,000	62.5
55,000	3,678,000	66.5
5,000	255,000	51.0

3(*c*) *Diesel Electric Plant.*

Total Installed Capacity (KW)	Total Capital Cost (£)	Cost per KW (£)
6,000	535,000	89
6,000	500,000	83
6,000	500,000	83
2,200	136,000	62

For steam plant the capital cost per kilowatt of installed capacity reduces with increase in the size of plant units as well as with the total capacity. The cases taken are installations in different parts of the country. In the United Kingdom and United States of America, steam plant is now being installed at a total cost of between £57 and £30 per kilowatt.

Gas turbine plant can be installed at approximately £50 per kilowatt. In the first two cases shown in 3(b) the total cost includes provision of accommodation for operating staff due to the remote location of the Power Stations.

Diesel plants are comparatively more expensive to install than Gas turbine for equivalent size. There is also the tendency for the cost/KW to increase with the size of the installation.

Hydro-electric generation, as already stated, has so far been limited to the Jos Plateau and the capital costs of the N.E.S.Co. installations are not available to the author. However, in general, hydro-electric schemes are noted for their high capital cost which is comparable with that for steam plant. The E.C.N. operated a small hydro-electric scheme at Njoke in West Cameroons when that was a part of the Federation of Nigeria. The installed capacity was 1,500 KW at a cost of about £137 per KW. The Kainji scheme is a multipurpose one and it is not possible to isolate accurately the cost for electricity generation alone. However, by the information contained on page 66 of the National Development Plan — 1962 —68, and ignoring financing costs, the capital cost for Power Plant section would appear to be about £140 per KW installed.

5. Transmission system

Another important element of capital expenditure is the transmission system. This is essential for the economic integration of the diverse and widespread energy resources of the country. Transmission lines are essential for three main purposes:-

(*a*) To transmit power from a hydro-electric station to the load centre. The distances involved are usually great and justified because of the very low generating costs associated with hydro-electric schemes.

(*b*) For bulk supply of power to load centres from outlying thermal stations.

(*c*) For interconnection purposes, that is, for transfer of energy from one system to another in case of emergency or in response to diversity in system peaks.

Transmission line costs depend mainly on the voltage of transmission adopted which in turn depends on the magnitude of power transmitted. Another factor which also has an effect on the capital cost is the nature of the terrain through which the line passes. This may make it necessary to use special tower structures or foundations.

Transmission line voltages in Nigeria are following the usual trend and have progressively increased from 11 kV for lines of over a few miles long to 132 kV for over 100 miles. Lines are now being constructed to operate at 330 kV and transmit power over distances up to 360 miles or more.

Typical average capital costs per mile of transmission lines at various voltages used in Nigeria are shown in Table 4.

TABLE 4

TYPICAL TRANSMISSION LINE COSTS

Voltage	Distance in Miles	Average Cost per Mile (£)
33 kV.	75	2,500
132 kV.	130	5,000
330 kV.	280	11,500

N.B. The above costs are for lines on steel structures and do not include compensations.

6.1 Operational costs

It is customary to divide the yearly total costs of supplying electricity into fixed and running costs. Fixed costs comprise every item of cost which is a function of time (and frequently of plant size) and which is incurred from year to year independent of output. Running costs, on the other hand, include all those items of cost which are proportional to the actual units generated.

The fixed costs are normally made up of the following items :-

(*a*) Interest on capital investment.
(*b*) Depreciation provision.
(*c*) Insurance, rents and rates.
(*d*) Fixed maintenance costs.
(*e*) A large proportion of the salaries and wages of operational and administrative staff since these are little affected by the output.
(*f*) Central administration and technical services.

The fixed costs are usually taken as directly proportional to the capacity of installed generating plant and expressed as a charge per kW per year.

Running costs are usually divided into :-

(*i*) Fuel costs
(*ii*) Running maintenance costs
(*iii*) Certain transmission and distribution costs.

The running costs are usually related to the energy produced and expressed as a charge per unit (kWh).

6.2 Depreciation

All the items of cost listed above, except the depreciation provision, do not present any serious problems to the cost accountant since they represent actual expenditure incurred. The depreciation provision, however, forms a large percentage of the fixed costs and, traditionally, is a sum put aside in a fund so that at the end of the plant life there is a matured sum equivalent to either the initial loan borrowed for investiment or sufficient to purchase fresh plant of equal cost. Having purchased an asset, that asset is regarded as reducing in value as a result of age, wear and tear, corrosion, obsolescence of equipment, or inadequacy of the equipment, necessitating its replacement. This decrease in the value of the asset is counterbalanced by the depreciation fund which increases as the value of the asset decreases. When the asset is finally thrown away, the depreciation fund should amount to the original outlay.

The depreciation provision may be based on either the straight line method or the sinking fund method. The straight line method is the more widely used in the Electricity Supply industry. It assumes a constant depreciation each year. The annual provision depends on the total depreciation and the expected life of the equipment and is independent of the rate of interest it may draw during accumulation. The sinking fund method is based on variable depreciation. In this method a fixed, predetermined sum is set aside each year and interest compounded on it periodically. The fixed sum is such that the total annual instalments together with the accumulated interest will equal the total depreciation.

In recent years arguments have arisen as to which of the methods is more appropriate but it seems generally agreed that both methods can be used depending

on the nature of business being carried out. A further complication has been introduced into the subject by the 'historical cost' versus 'replacement cost' controversy. In short, this is an argument as to whether the depreciation provision should cover only the actual (historical) cost of the plant currently in use or whether it should cover the cost of future plant which, owing to presumed continuous inflation, is taken to be more expensive. It is not, however, proposed to deal with this subject in detail here and attention has been drawn to it only because of its nature as an apparently arbitrary charge. Also it is an important factor in capital formation as well as rate or tariff design.

7. Sources of capital for development

As has already been indicated, a large scale capital investment programme is necessary to keep pace with the rapid expansion of electricity demand in the country. The main sources of capital for a Public Utility are as follows :-

1. Depreciation provisions.
2. Net surplus of total income over total expenditure.
3. Capital contributions from consumers.
4. Loans which may be direct loans from the Government, public subscriptions or external loans. Both the public subscriptions and external loans are, of course, normally guaranteed by the Government.

The first three sources add up to what is termed internally generated capital, i.e. capital provided from revenue. In developing countries like Nigeria where the capital available is usually not enough to meet all the necessary development schemes, it is usually helpful if the Public Electricity Supply Industry is permitted to operate in such a way that it is able to 'generate' a certain amount of its capital requirements. The only practical way of doing this is to maintain rates of electricity charges at a sufficiently high level to enable a large part of the development capital to be obtained from the revenue of the Undertakings. This is even now being done in more advanced countries where the other demands on capital for development is less pressing than in countries such as Nigeria.

The alternative would be to restrict rates to uneconomic levels under the wrong impression that industrial development would be assissted by so doing. This would usually create a false increase in demand for electricity which in turn would demand greater capital investment to meet it. Since the Supply Authority will be unable to contribute towards this capital requirement, the government will be compelled to provide all the capital, and in order to do this it may be necessary to set aside other development schemes or increase direct taxes.

In Nigeria we are fortunate in that this tendency was recognised in time and in 1956 a new tariff was introduced, setting the rates of charges at relatively high level, thus enabling the E.C.N. to provide increasing percentages of internal financing of development. This reached 32% in 1959/60 and a little over 50% in 1962/63. Sessional Paper No. 3 of 1957 setting out the Capital Structure of the Electricity Corporation of Nigeria shows that the Government recognised the need for the industry to stand on its feet and I take the liberty of quoting section 16 which reads as follows :- "An increased scale of charges for electricity supplied by the Electricity Corporation had become an urgent necessity by the end of 1955, costs outside the control of the Corporation having risen by 22 per cent since the tariff at that time was promulgated in April, 1952. Since the end of 1953 the Corporation has had to meet rises in the price of fuel and other materials and railway freight rates, and increased labour rates resulting from Hanbury and earlier awards. Conse-

quently a new tariff has been introduced, effective from June 1956, and this was designed, in so far as the Corporation was able to do so at that stage, to take into account not only the increased costs as known at that time, but also to contribute towards the increased capital charges which the Corporation will bear as the result of the proposed financial arrangements. The Government and the Corporation intend, therefore, that as soon as possible the Corporation will dispense with the subsidy in respect of losses on normal commercial operations; such subsidies not only represent a drain on the Government's resources but are also damaging to the prestige and morale of the Corporation. It is unlikely that the present electricity tariff will continue to provide sufficient revenue for the Corporation's needs in view of further increases in costs which have taken place in the past twelve months and the impact of depreciation charges on newly installed plants."

Again, on this question of rates, the International Bank for Reconstruction and Development Mission in their report (pages 287—288) noted as follows :-

"Nigerian power rates are not high, considering the stage of development the country has reached and the fact that the circumstances under which power is generated and distributed *are inherently expensive*!

"Lagos rates are low in comparison to those in many cities where operating conditions are similar. They are not much above those in countries like the United States, where conditions are very much more favourable to economic operation. In order that Electricity Corporation of Nigeria's accounts may be balanced, and the present drain on the government budget halted, we recommend that Electricity Corporation of Nigeria again increase its rates. However, such an increase should in no way be construed as cancelling the responsibility of Electricity Corporation of Nigeria's management to reduce costs."

It is significant to note that in spite of the views expressed in both the Sessional Paper No. 3 and I.B.R.D. report the power rates in Nigeria have not been increased up till now even though costs (particularly for fuel and labour) which are outside the control of the Corporation have increased considerably. This could only have been achieved by economies in operations.

Figure 3 shows the operational costs in pence per unit sold for the ten year period 1954 to 1963 broken up into the main constituent items. It will be observed that in spite of the increase in costs of labour, materials, etc. which has taken place since 1956, the cost of operation has been progressively reduced. However, further increases in costs outside the control of the Corporation which have recently taken place, make it unrealistic to keep rates at the present level much longer if the Corporation must be able to provide an increasing percentage of its estimated development capital expenditure from its internal sources.

8. Summary

Cheap and abundant electricity supply is very important in the economic industrial growth of any country. The demand for electrical energy in the world is growing at a faster rate than for all other energy resources put together. The necessary energy resources for electric power production are available in Nigeria, except perhaps, sources of atomic energy. The exploitation of these resources can be regarded as just beginning.

Capital costs are generally high compared with more developed countries and

this can be attributed to the small size of plant units and the fact that practically all the equipment is imported. Nevertheless rates are reasonable and it has been possible to keep rates firm for a long period by economies in operation.

9. Acknowledgement

The author wishes to thank the Electricity Corporation of Nigeria for permission and facilities to produce and read this paper and to use information on its operations as illustrations and references. He wishes, however, to say that all opinions expressed or implied are his and in no way represent the official opinion or policy of the Corporation. I would also like to thank the friends and colleagues who have assisted with the production of this short paper.

FIG. 1

ELECTRICITY SALES.

ELECTRICITY CORPORATION OF NIGERIA.

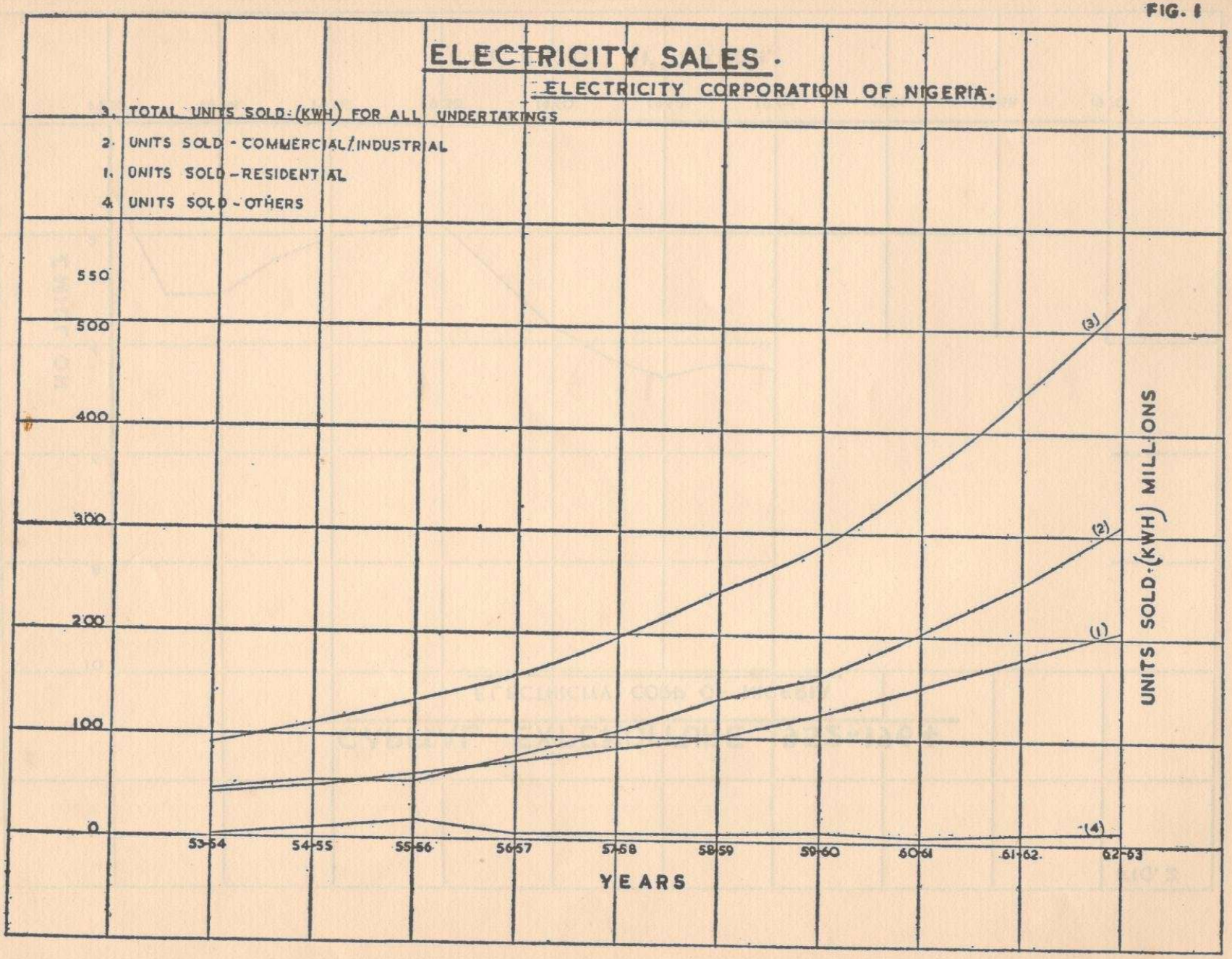


FIG. 2

CAPITAL EXPENDITURE 952-1964

ELECTRICITY CORP OF NIGERIA

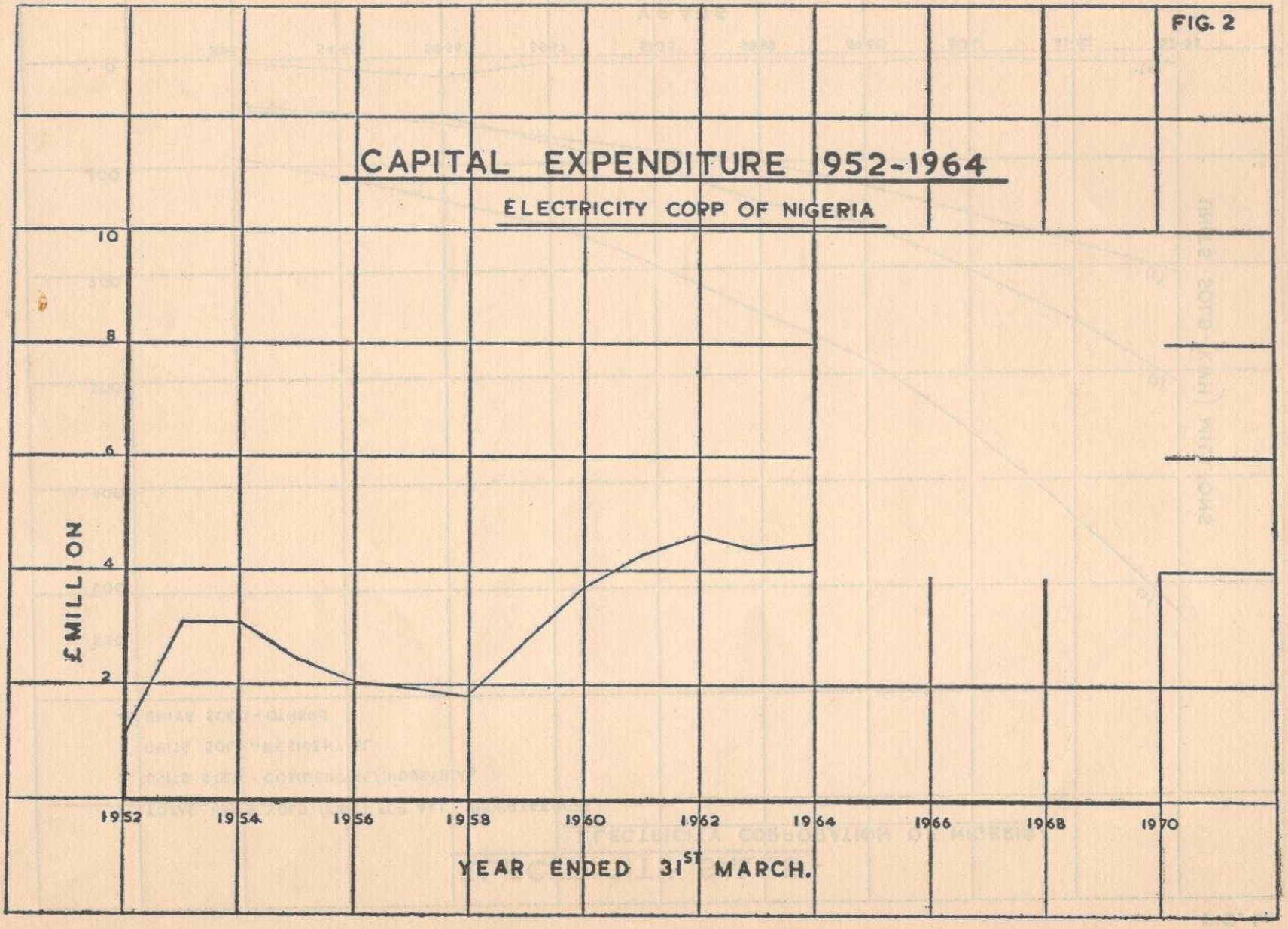
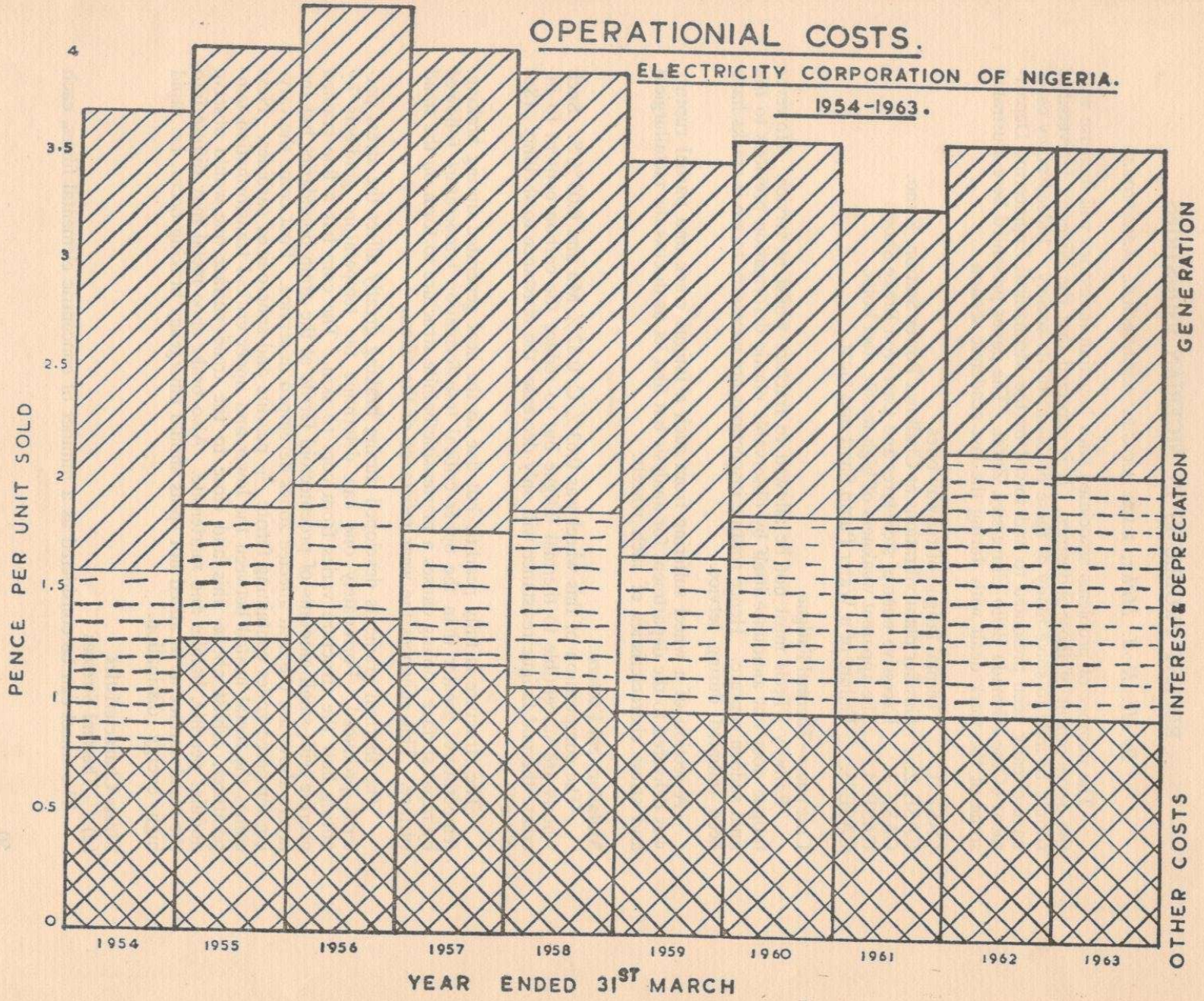


FIG. 3


OPERATIONIAL COSTS.
ELECTRICITY CORPORATION OF NIGERIA.
1954-1963.
PENCE PER UNIT SOLD
4
3.5
3
2.5
2
1.5
1
0.5
0
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
YEAR ENDED 31ST MARCH
GENERATION
INTEREST & DEPRECIATION
OTHER COSTS