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EXPANSION OF THE ELECTRICITY SECTOR IN LATIN AMERICA AND ITS CAPITAL REQUIREMENTS FOR 1960-70

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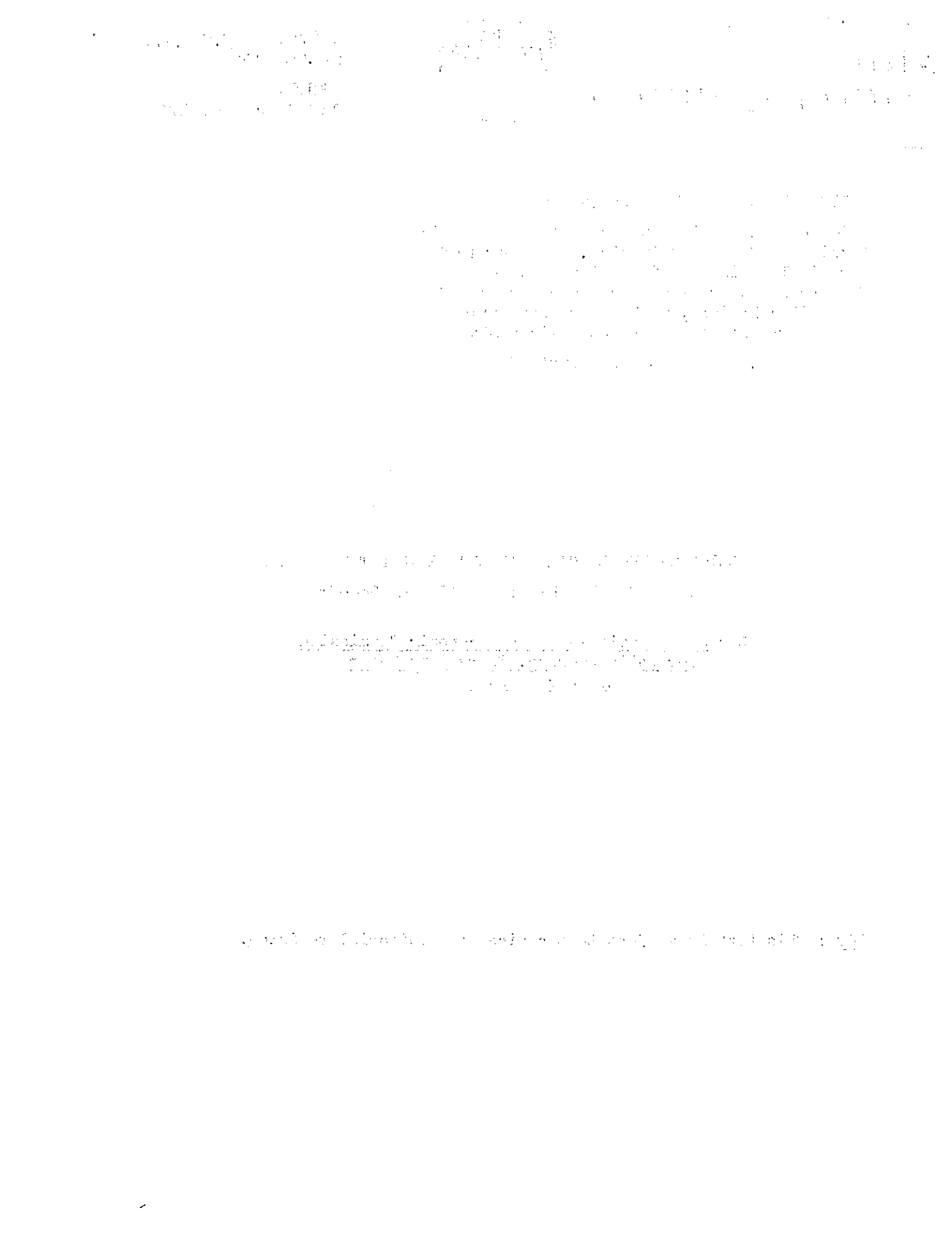
NOTE: This text is subject to technical and editorial revision.



Chapter I

GENERAL COMMENTS ON EQUIPMENT AND INVESTMENT REQUIREMENTS

In 1959 the Latin American countries produced 61,500 million kWh with an installed capacity of 16 million kW, 42 per cent of which represented hydraulic capacity.

Energy requirements for 1970 are estimated at some 200,000 million kWh, which will require an installed generating capacity of some 46 million kW. If the expansion programmes now in progress in Latin American countries are properly carried out - with a few necessary adjustments - this capacity will be available at the end of the decade. The predominance of hydro-electricity in these programmes, especially in the main producing countries, will reverse the proportion between hydraulic and thermal capacity in favour of the former (24 million kW) as compared with the latter (22 million).

In order to achieve this expansion, the Latin American countries will have to invest some 13,000 million dollars, which represents between 7 and 10 per cent of the total funds required for investment in conditions of normal growth.

Nearly 40 per cent of the investment in the electricity sector will have to be spent abroad. This will absorb about 6 per cent of the foreign exchange that will be available according to the forecasts of the capacity to import during the period in question.

1. Analysis of recent experience in Latin America

In 1959 Latin America consumed 51,000 million kWh, which represented a generating level of 61,500 million kWh. The difference represents losses in transmission and distribution, which amounted to 17 per cent of the total energy generated. Consequently, *per capita* generation was 310 kWh and *per capita* consumption was 250 kWh.

Output was based on an installed capacity of 16 million kW, of which 75 per cent was produced by public utilities and 25 per cent by self-supplying plants.

It is a well known fact that the electricity sector develops more rapidly than the rest of the economy, basically because it is a substitute

/for other

for other forms of energy. This rate of substitution is measured by the increase in the electrification coefficient.

Thus, in the ten-year period 1950-59 Latin America's gross internal product increased by 50 per cent (from 48,000 million to 72,000 million dollars, at 1959 prices), or at an average annual growth rate of 4.5 per cent. Electricity generation, on the other hand, increased at an annual rate of 8 per cent, which means that net electricity consumption per unit of product increased at a rate of 4.3 per cent.

Generally speaking, the increase in Latin America's electricity sector can be divided into two more or less equal parts: one follows the increase in the product while the other is linked to the rate of electrification of the economy.

The effort made during the ten-year period to expand the electricity sector, while falling short of requirements to judge by the unsatisfied demand at the end of the period and the various restrictions on supply which had to be imposed in many countries, can by no stretch of the imagination be considered insignificant. In fact, total output rose from 26,000 million kWh to 61,500 million kWh and the installed capacity of public utilities from 5 million to 12 million kW. These growth multipliers - about 2.5 - serve as a basis of comparison in analysing the required and estimated expansion for the next ten years, a subject to which the present study is confined.

The past pattern of electricity demand, divided into consumer sectors, is of interest from the point of view of the so-called indirect or second order projection methods - those relating electricity demand to specific macroeconomic variables. In this connexion, the first important fact that emerges is that the rate of electrification of the manufacturing sector in Latin America has lagged behind that of the rest of the economy during the past few years. This is attributable to the fact that, while the index of manufacturing production volume outstripped that of the gross product (62 to 50, both in 1950-59), the manufacturing sector's share of total electricity consumption dropped from 62 per cent in 1949 to 55 per cent in 1959.

Industrial consumption of electricity rose at an annual rate of 9 per cent which, with respect to the increase in the manufacturing output index

(an average

(an average of 5.5 per cent), corresponds to an electrification rate of 3.5 per cent. This, as already stated, is below the average for the economy as a whole.

On the other hand, domestic consumption of electricity - where electricity is used as an end product - increased during the past ten years at a rate of 9.8 per cent which, compared with a 4.5 per cent increase in available income, corresponds to an annual electrification rate of some 5.3 per cent for this type of consumption (measured in kWh per unit of income).

2. Electric energy demand in 1970

It has been estimated that 200,000 million kWh of electricity will have to be generated in 1970 in order adequately to meet requirements at that time. The following factors have been taken into consideration in computing or selecting this figure:

(a) Extrapolation of the experience of the last decade - which can be regarded as a good representative average since it includes both prosperous years and years of economic contraction - shows that some 174,000 million kWh will have to be generated in 1970. This figure, however, must be considered a minimum target, first because the expansion of supply failed to keep pace with demand as it developed in the past, and secondly because the Latin American countries are no doubt seeking to increase during the next decade the rate of product growth achieved during the period 1950-59. Table 1 shows this extrapolation for 1965 and 1970, country by country, including the extremes of the respective confidence interval for a 95 per cent level.

(b) A relatively optimistic estimate of Latin America's economic development, based on an analysis of demand in the main electricity consumer sectors, gives an output figure of some 200,000 million kWh. In reaching this total, it was assumed that the gross product and manufacturing output would increase at a rate of 6 per cent [1/] and 8 per cent respectively. It was further assumed that the latter would be achieved in equal measure by

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1/ A similar analysis, assuming three different rates of product growth, is made later in this report.

/increased productivity

increased productivity per employed person and the absorption of surplus labour. Moreover, use was also made of the experience of the more developed countries which shows that, as a rule, the rise of output in the manufacturing sector closely follows the increase in the specific electricity consumption of the sector. The rate of increase of the latter would therefore be about 4 per cent which, added to the rise in industrial output, gives an overall annual rate of increase of 12 per cent for electricity demand by this type of consumer. Applied to a period of eleven years, this corresponds to a growth multiplier factor of 3.55.

Thus, industrial demand for electricity would amount to 100,000 million kWh in 1970.

A relatively similar procedure was applied for non-industrial consumption, adding the growth rate of available income to that of the electrification of this consumer sector. It was assumed that the former would equal the rate of growth of the gross product (6 per cent) and that the latter would maintain the growth rate of the previous ten years (5.3 per cent, as indicated in the previous section). The respective growth multiplier factor is 3.12 and the electricity demand by this sector in 1970 therefore amounts to 72,000 million kWh.

By adding these two electricity demand figures and dividing the total by 0.87 - assuming that losses in transmission and distribution will drop from the present level of 17 per cent to 13 per cent by the end of the period under consideration - required output will amount to 198,000 million kWh.

(c) A similar form of calculation was applied specifically to the five major Latin American electric energy-producing countries, using their own income and industrial output statistics in order to have some idea of their respective electrification rates. These were subsequently applied to three different assumed annual product growth rates, called "minimum", "average" and "maximum", of 3.5 per cent, 4.5 per cent and 6 per cent respectively.

The results, shown in detail in table 2, were then extrapolated to Latin America as a whole, using 0.8 as the coefficient, which indicates the relative share of these countries in the total output for 1959.

/Table 1

Table 1

LATIN AMERICA: TOTAL OUTPUT (PRIVATE AND PUBLIC) IN 1959 AND ITS PROJECTION FOR THE YEARS 1965 AND 1970

(Millions of kWh)

Country	Total 1959	1965			1970		
		A	Trend	B	A	Trend	B
Argentina	9 850	13 202	14 866	16 743	18 014	20 947	24 379
Bolivia	426	431	506	595	476	583	718
Brazil	21 108	33 540	39 056	46 493	52 743	65 222	80 646
Colombia	3 348	5 879	6 433	7 038	9 887	11 087	12 437
Costa Rica	383	496	598	721	683	866	1 099
Cuba	2 806	4 333	4 680	5 091	6 492	7 168	7 980
Chile	4 598	5 014	6 074	7 354	5 984	7 661	9 778
Ecuador	332	500	628	791	803	1 067	1 431
El Salvador	235	424	452	481	716	778	881
Guatemala	243	367	403	443	536	614	687
Haiti	90	82	146	261	89	220	541
Honduras	86	104	123	145	134	167	209
México	9 800	14 766	15 989	17 315	21 724	24 041	26 611
Nicaragua	174	263	272	281	378	393	410
Panama	228	369	417	470	596	691	798
Paraguay	87	133	145	159	198	222	249
Peru	2 212	3 086	4 049	5 312	2 857	7 001	10 285
Dominican Republic	316	309	501	813	386	737	1 406
Uruguay	1 175	1 808	1 972	2 148	2 711	3 035	3 376
Venezuela	4 310	9 467	10 286	11 170	19 103	21 233	23 594
Latin America	61 807	94 573	107 596	123 824	144 510	173 733	207 515

Source: 1959: Document E/CN .12/560.

A = Lower extreme of the confidence interval.
B = Upper extreme of the confidence interval.

/The figures

The figures obtained were 140,000 million kWh for the minimum assumed economic growth in 1970, 170,000 million kWh for the average assumed growth, and 220,000 kWh for the maximum assumed growth.

3. Electricity capacity: present status and estimates for 1960-70

The estimated output in any given year can serve as a basis for estimating the electricity capacity required to obtain that output, assuming a specific level of utilization. However, it should also be borne in mind that the capacity must not only meet total energy supply requirements throughout the year but because of the special nature of the electricity industry, which cannot accumulate stocks for future consumption, it must also ensure that it can meet maximum power demand. In other words, both the ordinates and the area of the load diagram set limits on output capacity.

Critical periods may thus result from a shortage of capacity or of energy. In a country where the generating capacity is wholly or predominantly thermal, only the first of these shortages is important. On the other hand, in a country where capacity is wholly or predominantly hydraulic, with large storage plants, power is always available to meet peak demand but here periods of prolonged drought create critical conditions for the producer and ultimately for the consumer as well.

At the end of 1959, some 16 million kW of installed capacity, of which 12 million kWh were represented by public utilities, were available in Latin America both through public utilities and industrial self-suppliers. Of the 12 million kW, slightly more than half was in the form of hydroelectric capacity. This proportion is reduced to 42 per cent as a result of the predominance of thermal units (in a proportion of 6 to 1) in self-supply plants.

Of the total of 16 million kW, the five major producers of electric energy - Brazil, Argentina, Mexico, Venezuela and Chile - account for 75 per cent (in round figures: Brazil - 4 million kW, Argentina and Mexico - 3 million kW each, Chile and Venezuela - 1 million kW each).

If the electricity projects already adopted or currently under consideration by the Latin American governments, and especially those of the five major producing countries are properly carried out, some 30 million kW

/Table 2

Table 2

ESTIMATES OF THE ELECTRICITY OUTPUT REQUIRED AT VARIOUS RATES OF ECONOMIC GROWTH

(Thousand millions of kWh)

Country	Minimum rate assumed	Average rate assumed	Maximum rate assumed
	1963		
Brazil	24.4	26.2	30.7
Argentina	23.5	25.2	29.7
Mexico	13.3	14.3	17.0
Venezuela	9.2	9.8	11.0
Chile	6.4	6.6	9.3
Total	76.8	82.1	95.7
	1970		
Brazil	31.8	35.6	44.8
Argentina	37.8	50.1	68.9
Mexico	18.3	20.4	27.7
Venezuela	18.2	20.1	25.2
Chile	8.0	8.6	10.4
Total	114.1	134.8	177.0

Note: A few comments about these figures, some aspects of which may raise a few questions, seem warranted. It may seem surprising, for instance, that the figures for Argentina, which closely follow the 1965 figures for Brazil, should be so much higher than the latter for 1970. The relative difference between the two in 1959 can clearly not be maintained in view of the fact that the disparity in their respective rates of development during the previous ten-year period disappears in the projection, which is based on the same presumed rates of development in each column. But this does not explain why the order of the two countries as producers of electric energy should be reversed. The explanation seems to be that there is an anomaly in the Brazilian figures resulting from an under-estimate by the industry in measuring the extent of self-generation.

If the annual electrification rate of the industrial sector is assumed to be about 3.5 per cent instead of the figure provided by previous data, the adjusted figures in respect of Brazil would be as follows:

	Minimum rate assumed	Average rate assumed	Maximum rate assumed
1965	28.7	30.6	36.5
1970	41.2	46.3	61.5

An adjusted figure should also be computed for Argentina. Here, the rate of electrification of the industrial sector during the past five years (over 11 per cent), an unduly high figure attributable basically to the very low rate of expansion of the manufacturing sector during that period (less than 4 per cent or one-third the rate in Brazil during the same period), is reduced to 3.5 per cent. The adjusted projection for output in Argentina would then be:

	Minimum rate assumed	Average rate assumed	Maximum rate assumed
1965	16.4	17.7	20.5
1970	24.8	27.8	36.0

/of additional

of additional capacity will be available by 1970, for a total available installed capacity of 46 million kW. (See table 3.)

In addition to this net increase of 30 million kW, the proper replacement of some existing equipment will have to be provided for, amounting to between 3 and 5 million kW.

The analysis of the region's electricity projects shows that the proportion of the total new generating capacity that will be hydroelectric will vary between 55 and 62 per cent. Whether the proportion is nearer to the upper or lower figure will depend essentially upon the policy of the Argentine Government with respect to the execution of the large-scale hydroelectric works planned for that country.

Thus, even if the expansion of Argentine electricity during the decade is purely in the form of thermal capacity, the proportion of hydroelectric output will increase in the next few years.

This is primarily due to the impact of the Brazilian programme on the total figures for Latin America since this programme represents more than one-third of the region's total proposed electricity expansion and nearly one-half of the additional hydraulic capacity to be installed. This assessment is in absolute terms since in relative terms the proportion of hydraulic capacity is higher in the Chilean programme, for example, in which 80 per cent of the new capacity is hydraulic, than in Brazil, where the proportion represented by hydroelectric capacity in the goal set for 1966 is something over 66 per cent.

It should be pointed out that some 7 million kW are currently under construction in Latin America, while an additional capacity of 28 million kW is in the project study stage, although this does not mean that final plans have been prepared in each case.

As stated above, account should be taken not only of the new installed capacity envisaged for the next decade, but also of the replacement of obsolete equipment, both generating equipment and equipment for transmission and distribution. Unlike the provision of additional capacity, the replacement of equipment, particularly of low-yield thermal units, is to some extent optional since it depends on the return that the investment in replacement will produce compared with the return on other possible uses of

/Table 3

Table 3

LATIN AMERICA: ESTIMATED CAPACITY IN EXPANSION PROGRAMMES

(Millions of kW)

Country	1959	1965	1970
Brazil	3.9	8.0	14.0
Mexico	2.7	5.5	8.0
Argentina	3.0	4.0	5.2
Chile	1.1	1.7	2.6
Venezuela	1.3	2.2	3.8
Colombia	0.9	1.6	3.1
Cuba	0.9	1.7	3.2
Peru	0.7	1.2	2.0
Uruguay	0.3	0.5	0.9
Central America	0.4	0.6	0.9
Other countries	0.7	1.2	1.8
Total	15.9	28.2	45.5

Source: National electrification programmes analysed in the text.

/the funds

the funds concerned, either in the electricity sector itself or in other sectors of the economy.

Much the same is true with respect to the gradual elimination of self-supplying plants, particularly diesel plants, in countries where, as in Argentina, there is a considerable proportion of such installations.

Save for those industries able to install generating plants of adequate capacity or for which the generation of electric energy is economically advisable because of their distance from public utility plants or where the nature of the manufacturing process (usually involving the use of steam) makes self-supply rational, self-supply - a common feature in industry in Latin American countries where public utilities impose restrictions on consumption - is antieconomical for two reasons. In the first place, the unit cost per installed kW is higher than that in a public utility generating plant, and secondly the direct input required is also higher. It is estimated that the increase in the former (capital investment) may amount to 100 per cent while the latter (direct costs) might be from 10 per cent to 15 per cent higher than for a high-capacity public utility plant.

Hence, a rational electricity policy must clearly seek to discourage the installation of additional self-supply capacity, except for the special cases referred to. The question then arises as to the policy to be adopted towards self-supply capacity already installed.

From the economic, as opposed to the book-keeping point of view, past investment expenditure need not be considered. Moreover, the resale value of this type of installation is very low because of the high cost of removal, transport and reinstallation, although its use may still be economically justified in remote low-consumption areas. The policy to be applied with respect to the use of thermal self-supply capacity already installed must therefore be determined by comparing the fuel savings (direct input) with the larger investment needed to replace it by public utility capacity. Thus, the problem is analogous to the replacement of out-of-date equipment with a high specific consumption by new equipment at the large public utility thermal plants. There are also points of similarity with the choice between hydro and thermal plants, which will be further discussed below.

/In all

In all these cases, the economic merits of present investment must be balanced against higher operating costs in future.

For all these reasons, there is a considerable element of uncertainty in estimating replacement requirements, the more so since the interconnexion of existing thermal plants with other generating plants, particularly of the hydraulic type, increases the economic yield in both cases and thus alters the degree of relative obsolescence. Thus, a thermal plant that is anti-economic when operating in isolation may well prove to be economic and therefore not need to be replaced by a new plant, if used, with a plant factor appreciably lower than before, as capacity to supplement a hydraulic plant or as a peaking unit in an integrated electricity system.

Subject to these reservations, it can be stated purely by way of indication that the replacement of existing generating plants over the next decade will amount to between 3 to 5 million kW.

As the economically useful life of a hydro-electric plant is longer than that of a thermal plant, and many of the former are of relatively recent construction, it seems likely that a higher proportion of thermal plants will need to be replaced.

The total capacity to be installed in the period 1960-70, including replacement, would thus be from 33 to 35 million kW.

Almost the whole of this total would represent new installed capacity in public utility plants. In fact, taking into account all the relevant factors, the present self-supply capacity of 4 million kW is not expected to increase by more than 50 per cent during the next ten years. It should be borne in mind that, with respect to consumer industries, many self-supply plants will be eliminated, particularly in Argentina and other countries, as the restrictions on supply which caused them to be built are removed. Thus the new capacity will be added in the basic industries sector where high inputs sometimes justify the installation of individual plants or when the industrial process concerned makes it economical to produce joint steam-electric power, and in the mining sector where an expansion in such fields as copper and petroleum is to be expected. However, even in the last case, the excess of existing productive capacity in the equipment concerned, and the unfavourable outlook for world demand conduce to the view that this

/increase in

increase in self-supply capacity is hardly likely to exceed 50 per cent for the whole decade.

As already stated, the present electrification plans and projects of the Latin American countries, if properly carried out, will, at the end of the period under consideration, provide a generating capacity of about 46 million kW. In order to reach the 200,000 million kWh of energy estimated for 1970, the degree of equipment utilization will have to be 4,350 hours per annum. In 1959 the average degree of utilization was 3,850 hours (61,500 million kWh with an installed capacity of 16 million kW).

In other words, in order to reconcile these statistics the annual utilization factor will have to increase by 500 hours, or 13 per cent, in the next ten years. There are two components of this factor to be analysed, namely the load factor and the proportion of reserve capacity in generating plants. Although there are reasons why the load factor should increase, the principal reason being the industrialization of the area's economies, it must be remembered that the removal of the restrictions on supply contemplated for major systems in the region in the near future will tend to reduce the level of the load factor, at least on a short-term basis. An analysis of the figures and of the situation in the various countries, and the consideration that the effect of abolishing restrictions will be less gradual than the advance in industrialization, leads to the conclusion that generally speaking there is not likely to be a substantial improvement in the load factor in Latin American electricity systems.

The outlook is more favourable with respect to reserve capacity, although it should be emphasized that the present margin is very narrow. Through the gradual interconnexion of power plants, there is a trend towards an appreciable reduction in reserve capacity requirements, which in the case of isolated plants are generally imposed by the need to use the largest generating unit for this purpose.

The interconnexion of consumer centres also tends to improve the load factors of the systems concerned by making it possible to take advantage of the differences between the demand diagrams. The extent of this improvement varies with the heterogeneity of the consumer centres that become a part of the network of consumption.

/Account should

Account should also be taken of the fact that current statistics for Latin America under-estimate the degree of utilization of installed capacity, since they include in this capacity many generating units, especially thermal units, which are virtually out of operation and are not used even in critical periods.

For all these reasons, it appears that an average utilization level of 4,350 hours is a reasonable aim to set for the end of the decade, although it represents a considerable increase compared with the present level, which is very low. According to the figures that have been worked out, there would be at that time some 24 million kW of hydraulic and 22 million kW of thermal capacity. Needless to say, if this increase is not achieved, a proportional increase in installed capacity would be required, involving additional investment.

In a normal year the same level of utilization as for 1959 (4,750 hours) might be assumed for hydroelectric power, or perhaps a slightly higher figure by reason of improved plant design and an increase in relative storage capacity. In these circumstances, all hydroelectric plants could generate some 129,000 million kWh a year. This would leave a balance of 76,000 million kWh to be generated by the thermal plants, which might require as much as 22 million tons of petroleum equivalent. In relation to a capacity of 22 million kW, this would mean an average utilization of 3,450 hours, and although this figure is fairly higher compared with that attained in recent years (3,300 hours in 1959), is well within reach since much of the thermal capacity would be of recent installation.

Even if average hydrological conditions are most unfavourable, or critical - as, for instance, if the degree of utilization of hydraulic capacity is 3,000 hours - a similar calculation will provide a figure of 5,800 hours as the level of utilization required for thermal plants, which is also within reach in view of the considerations outlined above.

It should be borne in mind, however, that under these conditions the amount of fuel required to generate the 130,000 million kW will be in the neighbourhood of 35 million tons of petroleum equivalent, or three times as much as was used in 1959. This will constitute a considerable drain on foreign exchange resources.

/A few

A few comments seem warranted on the practical limitations of the relatively optimistic conclusions which appear to emerge from the above analysis. In the first place, it will be noted that the primary concern was to obtain a sufficiently large total supply of energy since the Latin American resources for generating electricity will be predominantly hydraulic and the critical situations will therefore tend in general to be caused by a shortage of energy. However, there will be exceptions, and even if the proposed expansion plans are fulfilled to the letter, it does not seem likely, especially in relation to the large thermal systems supplying such urban centres as Greater Buenos Aires, that peak demand requirements could be fully met, particularly when present restrictions are abolished and the tempo of economic development and industrialization of the economic systems upon which they depend increases.

Secondly, the postulated level of utilization (13 per cent), while a reasonable target, will not be easy to achieve, especially in view of the narrow margin of reserve with which the major Latin American systems are now being operated. It is therefore desirable that present expansion programmes, particularly in the case of some countries, should be reviewed in the near future with a view to their possible broadening or amendment.

4. Cost and financing of an expansion of the electricity park in Latin America [2/]

As shown in earlier sections of this report, the Latin American electric industry will have to install 30 million kW of additional capacity and replace between 3 to 5 million kW of existing capacity in order to meet the estimated demand for electricity in 1970. The means of financing this expansion will be dealt with below.

Analysis of the expansion programmes in the different countries reveals a marked difference in their respective unit costs, which was to be expected in view of the lack of homogeneity in the overall Latin American picture with respect to availability of water resources, the cost of its utilization,

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2/ See also "Algunos problemas en el financiamiento de la expansión del sector eléctrico" (ST/ECLA/CONF.7/L.1.30)

the location of consumer centres in relation to the optimum position of generating centres, etc.

As far as generation is concerned, the disparity in unit costs is much greater for hydroelectric plants than for thermal plants. This confirms the experience of other areas. In fact, a study of recent installation costs in the United States shows that while the per kW cost for hydroelectric plants varies between 100 and 600 dollars, the range was considerably narrower for thermal plants, varying between 120 to 250 dollars. In Latin America the corresponding cost for hydroelectric plants ranges between 200 dollars, in the most favourable circumstances, and 500 dollars (availability always being measured in plant bus bars) while the cost for a thermal plant varies between 150 and 250 dollars.

Moreover, not only does the cost vary less in the case of thermal plants but the variation itself is largely explained by the economies of scale. Thus, while the programme recommended for Argentina by a group of consultants appointed for that purpose provides for an average cost of 150 dollars per kW of installed thermal capacity because of the large capacity of most of the proposed installations, this figure doubles as the size of the units is reduced, as a result of the smaller size of the consumer markets in countries of small economic potential.

An average figure of 200 dollars per kW has been estimated as the cost of installation of replacement power, taking into account the fact that virtually all of this power will be thermal and that the size of the new plants will tend to increase.

With respect to the transmission of energy from the generating plant to the consumer centre, the relative fixed cost of transport within the total figure for the electricity programme will, as is natural, depend upon the percentage of power generated hydroelectrically and the distance between the hydraulic plants and the large urban centres in the country concerned. Here too conditions vary considerably in Latin America both regarding the proportion of hydraulic output (ranging from expansion programmes providing essentially for thermal capacity to programmes in which 75 per cent of the capacity will be hydroelectric) and distance from consumer centres (relatively short in Brazil and long in Argentina).

/Table 4

Table 4

LATIN AMERICA: PROPORTION OF HYDROELECTRIC ENERGY IN THE EXPANSION PROGRAMMES OF THE ELECTRICITY SECTOR IN 1960-70

Country	Net additional capacity (millions of kW)	Hydroelectric energy (percentage)	New hydraulic capacity (millions of kW)
Brazil	10.1	60	6.1
Mexico	5.3	75	4.0
Argentina	2.2	10	0.2
Chile	1.5	67	1.0
Venezuela	2.5	84	2.1
Colombia	2.2	62	1.4
Cuba	2.3	5	0.1
Peru	1.3	84	1.1
Uruguay	0.6	43	0.25
Central America	0.5	50	0.25
Other countries	1.1	36	0.4
Total	29.6	57	16.9

Source: National electrification programmes analyzed in the text.

/The cost

The cost of these transmission lines (including sub-stations) will apparently be between 20,000 and 50,000 dollars per kilometre, depending upon the tension adopted, the volume of energy to be carried and the nature of the terrain.

An analysis of the expansion programmes adopted or recommended in the Latin American countries, to which some adjustments have been made, shows that the average cost per kW will be about 415 dollars. (See table 3.) To this figure must be added the cost of replacement, estimated at 200 dollars per kW. This brings the total funds required to about 13,000 million dollars (30 MW of new power at 415 dollars per kW plus replacement of 4 MW at 200 dollars per kW), which represents a unit investment of some 380 dollars per kW. This would correspond to a cost of about 300 dollars per kW in respect of generation and transmission.

Even if due allowance is made for the major technical improvements achieved in thermal generation - which have gradually reduced unit installation costs of generating capacity to below 150 dollars per kW in the case of large high pressures/high temperature units - and the fact that much of the area's hydraulic potential can still be utilized at relatively low cost,[3/] the resulting average figure seems to be somewhat low. The explanation may well lie - wholly or partly - in the omission from some electricity plans of the costs represented by electric energy distribution grids.

It should be borne in mind that modernization and expansion of electricity lines and grids are not merely an additional current investment amortized by reduced losses in the future, but that up to a certain point they are a substitute for alternative investments in generating facilities. These losses amount, in terms of energy, to an average of 17 per cent - including transmission and distribution losses as well as consumption in the generating plants themselves. Furthermore, as such losses are approximately in proportion to the square of the amperage carried, they reduce

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3/ Thus, the unit costs for the large Brazilian hydroelectric plants under construction, such as Furnas and Tres Marías, are estimated at about 200 dollars in plant bus bars.

the power available for consumption, as compared with the power available at the plant bus bar by more than 20 per cent during peak hours. It is therefore obvious that any investment in transmission lines and distribution grids, whether primary or secondary, which tends to reduce this figure will serve also to reduce the investment in new generating capacity required for a given level of consumer demand.

Apart from under-estimation of the cost of improving and expanding distribution grids, which seems to occur in many government electricity plants, past experience has shown that the estimated cost of such plans is usually unduly optimistic. In fact, an analysis of the frequency of errors in estimating future costs shows that underestimates are more common than overestimates.

Thus, even if the gross investment in the electricity sector required to provide an installed capacity of some 46 million kW by 1970 is estimated in round figures at 13,000 million dollars, the actual cost may well exceed that figure. Moreover, there is always the possibility that the programmes of some countries whose recent rate of economic development has been unsatisfactory may have to be revised upwards towards the middle of the decade. It is felt, nevertheless, that the amount needed will hardly exceed 15,000 million dollars.

As to the breakdown of this total figure into local currency and foreign exchange costs, the regional average of foreign exchange required (based always on the plans concerned) is 38.5 per cent, fluctuating between one-third for a country with a greater internal capacity to provide heavy electrical machinery and equipment, such as Brazil, to two-thirds or more for countries with a weak industrial structure. Mention should be made, incidentally, of the fact that a reduction in the relative share of investment in foreign currency - a favourable development from the point of view of overall economic development - sometimes creates difficulty from the financial standpoint since financing by international agencies, foreign private banks and the so-called consumer credit, covers only the cost of imported machinery and equipment. Hence, the financing of local currency costs is at times a difficult problem, apart from the fact that when funds are provided by the State - either directly through the budget or indirectly through government

/investment banks

investment banks and similar agencies - it is common for such financing to have an inflationary effect on the national monetary systems.

An analysis must now be made of the relative importance of investment in electricity in relation to the total investment required to ensure a satisfactory rate of economic development; a study must also be made of the amount of resources available and what part of them can be devoted to capital formation which will, on a series of different assumptions, generate internal savings, both privately and publicly. A comparison of the two figures will show the deficit - or perhaps the surplus - which will have to be covered from foreign sources, if the area is to continue to develop at the desired rate.

In determining these figures, the three basic macroeconomic variables are: (a) the rate of product growth; (b) the product-capital ratio; (c) the internal savings coefficient. The savings to be generated by the system itself will be the sum of each pair of values of the product growth rate and the internal savings coefficient, based on the region's current gross product. In turn, the area's investment requirements are obtained for each pair of values of the product growth rate and the product-capital ratio.

Hence, the internal savings deficit or surplus with respect to the capital requirements of the Latin American economies can be determined from two values of these three parameters.

As seen earlier, the plans to expand electric output during the next ten years are roughly consistent both with the extrapolation of past experience and the projection of consumption, assuming a normal rate of growth, as much with respect to the increase in available personal income as to the tempo of industrialization in the area (4, 5 and 8 per cent a year respectively).

A dynamic approach must be made to trends in the sectoral investment coefficient for the electricity industry. Considering that the coefficient of electrification of the economy - i.e., the number of kWh generated for each dollar of gross product - increases with product, a given rate of increase in product should be accompanied by a more than proportional increase in electricity consumption. This means that unless the coefficient

/of overall

of overall investment increases with product, investment in the electricity sector must represent an increasing percentage of total investment in the economy.

Even supposing that the coefficient of savings and the coefficient of investment increase gradually as is supposed in the majority of development programmes for the area, it does not seem likely that this will be sufficient to compensate for the increase in electrification. It is therefore reasonable to conclude that during the forthcoming years, the Latin American countries will have to devote the increasing proportion - and doubtless more than at present - to investment in the electricity sector and that this proportion will be larger the more intense the rate of economic development and the rate of investment in heavy industry.

Experience in some Latin American countries has shown that when the sectoral coefficient of investment was close to 10 per cent, the situation as regards electricity supply was relatively satisfactory. This occurred for example in Chile, Mexico, Uruguay and Venezuela very recently. On the other hand, in other countries where the coefficient was much lower than 10 per cent, there were shortages of electricity supply. Such was the case in Argentina and Chile before 1958.

The financial effort required in order to expand an electricity system to allow it adequately to meet demand is considerable because of the high product-capital ratio and becomes even greater as the rate of growth of the demand it is expected to meet increases.

In the case of the electricity industry, the product-capital ratio depends upon: (a) the initial investment cost of each kW of installed capacity; (b) the unit sales price of the power produced; (c) the level of utilization of the installed capacity.

Annual investment requirements will essentially depend, in turn, on the unit cost per kW and the rate at which the system expands in order to meet demand. One method by which to finance this investment is to use the operating profits obtained from the level of rates, the percentage of unit profit (per kW sold or produced) on those rates, and the volume of power sold.

As an indication of the size of these respective figures, it should

/be pointed

be pointed out that, based on Latin America's consumption of electricity in 1959 and assuming an annual increase of 11 per cent in demand, each tenth of a dollar cent of profit per kWh sold would produce 1,000 million dollars in the period concerned. Thus, the level of profit required for various levels of self-financing of the total investment required can be computed easily.

5. Electricity financing and the balance of payments

The effect of the required expansion of the electricity system in Latin America on the balance of payments is of great importance in relation to the trade policy both of countries inside and outside the area, and of international finance agencies.

The two main headings under which electricity generation affects the balance of payments are the import of equipment and material needed in the provision of electric power - for generation, transmission and distribution facilities - and the import - or in the case of producer countries the decline in exports - of fuels.

As has already been seen, the plans of the different countries and in particular of the main producers of electric energy provide for gross investment over the next decade of at least some 12,000 million dollars, somewhat less than 40 per cent of which, or some 500 million dollars per year, corresponds to imports.

The resulting figure should be compared with the current import capacity of the area which is equal to the value of exports plus the net balance on the services account, which was 7,140 million dollars in 1959. If the capacity to import remained invariable in absolute terms, the result would be that on an average the import of electrical equipment would require something less than 7 per cent of the foreign currency available in the area. This would be an extreme assumption, as it is highly improbable that Latin America would maintain a satisfactory rate of development if the quantum and value of its exports, which are the main components of the capacity to import, remain invariable.

A somewhat less pessimistic assumption can be obtained from the recent trend of exports in terms both of the region's gross internal product and

/the total

the total exports of the western world. In the period 1955-59 the ratio between the value of exports and the gross product, both expressed in current values, dropped from 14.5 per cent in 1955 to 11.4 per cent in 1959. This was attributable less to the smaller percentage of exports in the gross product, in so far as volume indices are concerned, as to the deterioration in terms of trade.

Extrapolating to the end of the decade both the recent trend in the growth rate of the gross product (4.5 per cent at constant values) and the contraction in the relative contribution of exports to that product gives an annual average value of the order of 11,600 million dollars for exports by the end of the decade.

A similar figure is obtained by analysing the relative share of Latin America in visible international trade. A comparison of the region's exports with total world exports (both at f.o.b. values) shows that this share fell from 11.8 per cent in 1950 to 8.1 per cent in 1959.

The similar procedure of extrapolating the recent trend with respect both to the expansion of international trade and to the contraction in the relative share of Latin America gives a figure of 11,200 million dollars as the total for the region's exports by the end of the decade.

If it is also assumed that the net deficit in the services account will gradually increase up to 1,500 million dollars, particularly in view of the increase in government expenditure on servicing loans, an estimate of the order of 10,000 million dollars is arrived at for the region's current capacity to import by 1970.

If a linear trend in the growth of capacity to import is assumed for the decade, from about 7,000 to 10,000 million dollars, the total for the period will be 85,000 million dollars, of which imports of electrical equipment and machinery, which will probably be of the order of 5,000 million dollars, would represent slightly less than 6 per cent.

It is also useful to relate foreign exchange requirements for electrical equipment to the import component of capital formation in general, and to examine the effect of both on Latin America's balance of payments.

Imports of capital goods during the last five years represented about a third of total Latin American imports. The main absolute increase was

/under the

under the heading of industrial equipment and machinery, which at present accounts for more than half the total.

Gross internal fixed capital formation amounted to some 10,000 million dollars in 1957-58 (at 1950 prices, since in dollars at current values the figure would be about 12,000 million dollars), which in relation to the gross national product for the same period gives an investment coefficient of the order of 1/6.

A comparison of these figures with that for the imports of capital goods shows that the import component in capital formation in recent years has been in the region of 25 per cent. This average percentage is appreciably lower than that estimated for the electricity sector, for which the import component amounts to 40 per cent.

It should be noted that a given increase in the product implies a more than proportional increase in electrical capacity, whereas the capacity to import tends to increase less than the product. Consequently the higher the growth rate in Latin America in the next few years, the greater will be the relative effect of electricity development on the region's balance of payments, unless import substitution for items of electrical equipment succeeds in compensating for the joint effect of the two phenomena referred to.

With respect to fuels, of the total power generated in 1959 approximately half was thermal power, the higher level of thermal installed capacity being counterbalanced by the lower level of utilization for this equipment compared with hydroelectric installations. Specific fuel consumption for thermal generation in 1959 was extremely high, being estimated at 0.5 kg. of petroleum equivalent per kWh, which is an indication of the low efficiency of most existing units. Thus fuel consumption in 1959 was of the order of 12 million tons of petroleum equivalent.

The analysis of the electricity expansion plans of Latin American countries indicated that the hydroelectric capacity planned for the end of the decade is in the region of 24 million kW. It was also stated that in a normal hydrologic year this capacity would generate 115,000 million kWh, leaving the remaining 85,000 of estimated demand to be provided by thermal plants.

/It should

It should be borne in mind that the additional thermal capacity to be installed during this period, and the capacity represented by the replacement of obsolete units, will have a yield much higher than the present yield, which may be estimated as between 0.24 and 0.27 kg/kWh. Taking into account the existing units which will not be replaced, whose degree of utilization can be assumed to be less than the average for thermal equipment, a figure in the region of 0.3 kg/kWh can be postulated as a reasonable aim by 1970.

On this assumption the estimated generation of about 85,000 million thermal kWh would require a fuel consumption of the order of 25.5 million tons.

A unit value of 15 dollars a ton can be postulated for this fuel, a figure closer to f.o.b. than c.i.f. prices. In this case the total expenditure (or reduction of income) in the Latin American balance of payments under the heading of thermal generation in 1970 would be over 380 million dollars. Assuming a linear shift in fuel consumption from the level of 12 million tons a year at present to 25.5 million tons by the end of the period, the grand total of such imports (or the reduction of potential imports) would be of the order of 2,800 million dollars.

If the foreign exchange expenditure for fuel consumption is added to that for equipment, the total amounts to 9 per cent of the capacity to import estimated for the period on the basis of the assumptions made above.

The impact will in fact be less than this. Thus if there is an increase in the internal production of fuel in the region, the reduction in income in the balance of payments on account of fuel consumption would be calculated with respect to a potential balance which would include possible fuel exports, and there would be no real reduction in the present capacity to import.

The foregoing analysis naturally applies only to an ideal average situation for Latin America as a whole. The actual situation in each country may differ substantially from the average in accordance with a number of factors, including industrial capacity, volume of internal fuel production, decisions respecting the obtaining of foreign exchange loans, investment of foreign capital, and so forth.

How can this foreign exchange component of the investment requirements for the electricity sector, analysed above, be financed? In view of the

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major role played by the International Bank for Reconstruction and Development (IBRD) and the Export-Import Bank (Eximbank) in this type of financing, it is appropriate to analyse briefly the part these institutions have played in the past and what may be expected of them both, and of the recently established Inter-American Development Bank (IDB), in the near future.

In the 1950-59 decade, loans from the first two institutions for electricity development projects in Latin America amounted to about 600 million dollars, of which about two-thirds came from the IBRD and one-third from the Eximbank. Since during the next ten years about 5,000 million dollars in foreign exchange will be required for electricity expansion in the region, it is clear that unless these two bodies, together with the IDB, can substantially increase the rate of their electricity loans to Latin American governments, those governments must increasingly resort to other sources of finance, internal or external.

It does not appear either practicable or appropriate for these institutions to divert to the electricity sector funds that are now going to other sectors, since for the most recent period loans for electricity development represented nearly 60 per cent of all loans to Latin America by the IBRD, and although for the Eximbank the corresponding figure was only 10 per cent, it was 57 per cent of the total for electricity loans throughout the world made by that bank.

Thus the best hope lies not in a change in the structure of the loan portfolios of these institutions, but in an extension of their funds to enable them to provide more adequately for the needs of the various economic sectors, including in particular the electricity sector.

The contribution of these international financial institutions represented approximately a third of the imports for capital formation in the electricity sector during the last decade. If this proportion is to be maintained, the loans concerned should increase during the next decade to an average of over 150 million dollars a year, which in view of the rate at which these loans have been granted during the last 18 months seems a reasonable target.

That would still leave a substantial percentage to be covered either by the country's current foreign exchange earnings or by foreign private capital. As previously stated, there has been a steady decline in the

/contribution of

contribution of foreign private capital to installed capacity in Latin America. Consequently it cannot be expected to finance foreign payments in excess of its present contribution, which is of the order of 20 per cent. On this assumption, which is rather optimistic, foreign private capital would provide the region with capital goods of foreign origin for the electricity sector to the value of about 100 million dollars a year.

Credit will of course also be available from the suppliers of machinery and equipment, who are in turn usually financed by government bodies for the promotion of exports in the large industrial centres of the northern hemisphere. However, these credits, although they are of temporary help in alleviating critical situations in external financing, do not provide a basic solution, since they generally relate to short or medium term transactions which are unsuitable for industries with a high capital density and long amortization periods like the electricity industry.

6. Some observations concerning decisions in the electricity sector

The failure to undertake a thorough study of present conditions in the electricity sector, including plans for future action, has for many years constituted a serious impediment to an adequate development of the sector. The situation has improved considerably over the past few years and there is scarcely a country today that has not carried out this kind of study, conducted either by experts in government agencies responsible for electricity programmes, by international organizations or by foreign consultants.

A distinction should nevertheless be made between studies which are also plans for action, decided upon by the governments concerned and the national agencies responsible for the electricity sector, and those that are merely reports prepared by experts whose advice has been sought, without the government concerned having yet taken a specific decision to adopt the recommended programme, or any other plan, and to entrust its execution, or at least its supervision and co-ordination, to a given government agency with the legal powers and practical means of carrying out this function. In the absence of any clear-cut decision by the government the programme, however thoroughly studied and prepared, can obviously be only an expression of opinion by its authors.

/Even in

Even in cases where the government has decided upon a specific programme of action in a Latin American country, subsequent developments very often differ considerably from the estimates and the policy formulated in the plan. The reason for this is either a lack of funds to finance the proposed projects, lack of co-ordination with private concerns also providing public utility services or, again, the absence of an institutional structure for the electricity sector which would be compatible with the implementation of the programme decided upon.

For example, plans usually include provisions for an increase in the installed capacity of private companies, but this increase is in fact subject to prior conditions - such as adjustments in rates, amendments to legislation regulating public utilities, and provisions to attract domestic and foreign capital - which are not always fulfilled as implicitly or explicitly provided in the plans.

Another detrimental factor can be delay in deciding on one of several widely varying alternatives when whatever decision is taken will have considerable economic repercussions. This applies, for example, to Argentina with respect to the execution or postponement of projects such as Chocón and Salto Grande, and to Mexico and Venezuela with respect to standardizing the frequency of their networks and connecting the networks in their major cities with the grid for the rest of the country.

It is appropriate to review briefly the role of private enterprise in programming the expansion of the electricity sector and to stress the need for adequate co-ordination if such expansion is to be on a rational basis.

At the end of 1959 the share of private companies in the installed capacity of the public service was about 54 per cent of the total. During 1960 this share dropped to 42 per cent as a result of the expropriation of the Cuban company and the purchase by the Mexican Government of the two major electricity companies financed by foreign private capital. These two measures combined represented an addition of some 1.4 million kW to the capacity of State-owned plants and a corresponding reduction in the share of private companies.

The role of private enterprise in the distribution of electric power to the consumer and its resulting responsibility in the modernization and

expansion of the networks concerned are much greater than in the case of power generation. In fact, some State-owned companies engage purely or chiefly in power generation and sell large quantities of power en bloc to private concessionaires - particularly in the major urban centres in the area - which supply it to the consumer.

This creates a problem with respect to the programming of investment in the electricity sector, because these privately financed companies, for reasons which need not be gone into here, often fail to modernize or expand the distribution network at a rate consistent with that for generation or transmission.

Lastly, the variety of services provided by the component sectors at the various stages of generation, carrying and distribution of power requires the establishment of economic tariff systems which fully reflect, at each level, the capital as well as the current costs essential to the provision of an efficient service.

One of the chief problems in the formulation of any programme to expand the electricity sector is the selection of the type of generating plant to be installed, particularly the choice between thermal and hydro-electric plants. A few observations might be made here in view of the considerable discussion to which this point has given rise.

It should first be borne in mind that very seldom must a choice be made between a separate thermal and hydroelectric plant. It is usually a question of expanding an interconnected system of generation and consumption. Consequently what is needed is an economic study of the original system as supplemented in one case by a hydroelectric plant and in the other by a thermal plant. The question is even more complicated when programmes include a series of successive stages over a period of time, because the inclusion of each new generating plant in the system alters the conditions in which the system operates and therefore affects the relative yield of the plants already in operation.

The problem is similar to the analysis of alternative investment programmes in relation to the economic system as a whole. The existence of external economies means that each single investment affects the yield of the others. Hence, it would be wrong to analyse projects individually or

/to choose

to choose one rather than another by comparing their advantages. The theoretically correct solution is to compare the advantages of the various alternative programmes considered together.

Similarly, it is usually meaningless to say that any particular hydroelectric plant is more or less suitable than the equivalent thermal plant. The proper course is to compare, inter alia, the overall electricity expansion programme with the hydroelectric plant and, as an alternative, with a thermal plant.

Secondly, in analysing the relative advantages of two different investment programmes in the electricity sector, another problem is that of the rate of interest and the periods of amortization decided upon. A plan providing for a greater proportion of hydroelectric capacity will usually have a higher investment cost and a lower operating cost than an alternative plan providing for a greater proportion of thermal capacity. In the final analysis, this means that a comparison must be made of the expense involved at various points over the period of time concerned, which must therefore be converted into a standard unit by applying the rate of interest on the capital, a procedure by which the economic yield of either programme throughout its useful life can be determined. A lower rate of interest means less abstention in future consumption due to present investment, and thus favours high capital density investments. Accordingly, this effect of the interest rate means that hydroelectric power is comparatively disadvantageous in the less developed economies, where the rate is higher because of the relatively greater shortage of capital.

It should nevertheless be noted that in under-developed countries the higher interest rate is partly counterbalanced by the longer amortization periods which may be used in computing the overall capital cost coefficient; this is because, in view of the price structure in those countries, equipment does not become obsolete as quickly as it does in more advanced economies. Consequently the difference in the capital cost coefficient will be less than in the interest rate.

While the selection of the interest rate to be adopted in comparing the relative advantages of two or more electric power investment programmes is most difficult, and cannot be made on a merely quantitative basis, it is

/clear that

clear that in any event the factors mentioned above must be taken into consideration, and that over-simplified and ill-conceived formulas, such as using the bank rate at which external funds are obtained or the bank rate predominating in the internal monetary system, should be avoided. A distinction should be made between the nominal cost of capital - either for the State or for private enterprise - and the actual cost to the economy as a whole, taking particularly into consideration the fact that alternative investments within or outside the electricity sector itself will have to be sacrificed. The yield of these alternative investments, such as other major public works to be undertaken by the State - is one suitable criterion for determining the interest rate to be used in the calculations.

In the case of multiple purpose projects such as hydroelectric projects, it should also be remembered that the investment corresponding to the production of electricity will be lower because of the other benefits to be derived from such projects.

An analysis of existing plans for electricity expansion in Latin America shows that calculations of this kind are not usually made. In some cases there are practical reasons for this. One is that governments are handicapped in presenting a case to international financial agencies for the other investment projects that would absorb the additional funds for a mainly hydraulic project, compared with a thermal project, because studies similar to those made for the electricity projects are not available for the other public investment projects.

Even if it is assumed that an adequate interest rate has been selected which represents the marginal yield of investment funds at the level provided for, it should not be forgotten that in making a comparative analysis based on average annual costs, the problem of priorities over the period of time concerned is largely ignored. Both in Latin America and in many other parts of the world, the need for a high short-term increase in the output growth rate is stressed. In the present situation, estimated investment requirements exceed the present level of savings less because of the low savings coefficient than because of the low output coefficient. In these conditions, capital funds might well be concentrated on investments which contribute to a more

/rapid increase

rapid increase in the total output, which are not always those producing the highest yield over the long term.

This illustrates a fundamental point in choosing between hydroelectric and thermal plants in an electricity expansion plan. While there has been much discussion on the subject, the position of the contending schools of thought has not always been clear with respect to the assumptions made. The fundamental distinction, from the standpoint stressed here, is that an investment plan to raise output as much as possible by 1965 may be very different (although in exceptional cases it might be identical) from a plan to do the same by 1985.

Hence if for various reasons the government's main concern is the short-term yield on investment, a comparison of the annual cost of net profits at present values during the lifetime of the plants in question would not be a valid criterion for the decision.

7. Analysis of the cost of expansion and of the sectoral coefficient of investment

(a) Argentina

The relevant section of chapter II of the present paper analysed the conclusions of the consultants' report on electricity development in Argentina, and established the need to enlarge the goals set there with respect to electricity expansion.

A study of the financial aspects of the programme in question leads to the same conclusion. Thus, for example, the total investment proposed by the consultants for the 1960-70 decade (735 million dollars) is lower than the investment that it is proposed to make in Mexico during the first half of that period. As there is no substantial difference between the product of the two countries, this two-to-one proportion between the investment in the electrical sector hardly seems justified, even if no account is taken of the higher unit investment values for the Mexican expansion programme because it is mainly hydraulic.

The inadequacy of the targets set is also shown by relating investment in the electricity sector to the total gross fixed investment for the decade, assuming an annual growth rate of 4.5 per cent and a coefficient of

/investment of

investment of 21 per cent (the latter being the 1959 figure). On these assumptions, the investment of 735 million dollars would amount to 3.3 per cent of total investment, an extremely low percentage compared with that calculated for other countries in the region (see elsewhere in this section, and table 5), and not much higher than that for the 1945-55 decade, when it was 2.33 per cent, with results that are common knowledge.

From the standpoint of government decision, it seems necessary to adopt as soon as possible a definite stand with respect to the El Chocón and Salto Grande projects 4/ and, if approval is given, to establish an order of priority. Once this prior decision has been taken, it is essential to concentrate efforts on the strict fulfilment of the targets set for the programme chosen. An increase of not less than 50 per cent in these targets seems required compared with those set forth in the programme recommended by the consultants.

Table 5 accordingly shows a net addition of 3.3 million kW of installed capacity for the decade, representing a total investment of 1,250 dollars. This sum includes an extra investment of 150 million dollars, compared with the equivalent thermal plant, for the execution of one of the two great hydro projects referred to. Thus the unit investment cost would be 380 dollars per kW and the sectoral coefficient for electricity investment 5.6 per cent. The table also shows that despite the proposed increase in the targets of the electricity programme, the relative investment in the sector in Argentina would still be lower than in most other Latin American countries.

The consultants' report rejects the Salto Grande and Chocón constructions for the period ending in 1969, because of the larger investment that these projects would require. The annual cost criterion gives favourable results for El Chocón where the interest rate is up to 6.2 per cent, without multiple use, and where the rate is up to 10 per cent if the benefits of flood control and irrigation are included. For Salto Grande the annual cost criterion gives favourable results for the hydroelectric alternative if the interest rate is up to 13.2 per cent.

4/ The Argentine authorities are still studying the possibilities of developing the water resources of the Rio Negro system. They are considering submitting a request for a loan for this purpose to the Inter-American Development Bank, and obtaining other external financial assistance.

/Table 5

Table 5

LATIN AMERICA: INVESTMENT REQUIRED TO FULFILL THE ELECTRICITY EQUIPMENT PROGRAMME TO 1970

Country	Investment (thousands of millions of dollars)	Additional capacity (MW)	Unit investment (dollars per KW)	Sectoral coefficient of investment (percentage)
Brazil	4.44	10.1	440	6.6
Mexico	2.0	5.3	380	9.0
Argentina	1.25	3.3	380	5.6
Chile	0.65	1.5	435	10.0
Venezuela	1.1	2.5	440	5.5
Colombia	0.7	2.2	320	7.3
Cuba	0.85	2.3	370	7.5
Peru	0.4	1.3	310	7.5
Uruguay	0.3	0.6	500	-
Central America	0.3	0.5	600	...
Other countries	0.5	1.1	455	...
Total	12.49	30.7	407	

Source: National electrification programmes adjusted as indicated in the text.

Note: The unit investment costs obtained by analysing the programmes of the various countries are reasonably close to the values given in Precios y costos en la industria de la energía eléctrica de América Latina, (ST/ECLA/CONF.7/L.1.51), but somewhat lower than those calculated by R. Salazar in Fabricación de equipo y materiales para generación y distribución de energía eléctrica en América Latina (ST/ECLA/CONF.7/L.6.1). The difference arises mainly from the costs assigned to the improvement and expansion of distribution networks, which for most government programmes are of the order of 100 dollars per kW, whereas in the last-named document they are assumed to be over 300 dollars, although this also includes high tension transmission. As has repeatedly been stated, there are grounds for believing that the Latin American programmes tend to underestimate investment in distribution. Even so, it seems hardly likely that the average for the generation, transmission and distribution sectors together could exceed 500 dollars per kW.

/The investment

The investment required for hydro generation seems to have been somewhat overestimated. The firm capacity used in making the comparison is that estimated as available for 99 per cent of the time, whereas the practice in many countries is to regard as firm capacity that available for 95 per cent of the time.

With respect to the projects under consideration, the use of the 99 per cent criterion mainly affects Salto Grande, reducing its available capacity from 607 MW (on the 95 per cent definition) to 521 MW (99 per cent definition). The more regular flow of the river at El Chocón reduces the difference in available capacity (in this case 715 MW compared with 761 MW).

The overestimation of investment is also partly due to the characteristics of the transmission lines. Here again what seems to be an unduly large safety margin increases the cost, since two circuits are used, with a capacity of 93.5 per cent each for El Chocón and 95 per cent each for Salto Grande. As both projects are regarded as integral parts of a system with a reserve capacity amounting to 15 per cent of maximum demand, it seems clear that in both cases the capacity of each circuit could be reduced to 50 per cent of the total.

Thirdly, the investment required for the thermal alternative may have been underestimated, since the capital cost of producing the fuel is not taken into account.

In general it seems clear that restricting the period in question to that ending in 1969 nevertheless allows a sufficient period to decide upon large-scale projects with a lengthy construction period such as Salto Grande and El Chocón.

The decision recommended in the consultants' report, to postpone Salto Grande and El Chocón until the following decade, is based mainly on the wish to attain the objective in supplying the demand for electricity with the minimum capital investment.[5/]

This procedure is a clear example of the serious disadvantages of drawing up a sectoral expansion programme in isolation instead of as a

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5/ Consultants' report, Vol. I, p.115.

harmonious element in the general development of the economy, taking due account of the interdependence of its various sectors. The truth of this can be demonstrated by taking the extreme example of a series of isolated programmes all based on the criterion of minimum investment with the aim of economizing capital; this would lead to an under-utilization of total resources and to a development programme that would not make the best use of the country's potential with respect to capital formation.

If, as usually happens, increasing the proportion of hydroelectric capacity in the net additional capacity required by a given rate of development means increasing the unit investment, the approach should be to compare the marginal productivity of each successive capital input for the various proportions of hydroelectric capacity in the total with the marginal productivity of the same inputs in other alternative investments within the sector, in generation, transmission or distribution, or in other sectors.

This is all the more necessary because, as in Argentina, the unfortunate experience of certain countries in Latin America and elsewhere shows that the relative stagnation of the areas known as under-developed is due as much or even more to the lack of rational distribution of capital among the various sectors as it is to the lack of capital.

(b) Brazil

The estimated cost of expanding installed capacity by 5.3 million kW during the period 1957-66 is 2,340 million dollars, giving a unit cost of 440 dollars per kW. This estimate is based on calculations by the Banco de Desenvolvimento Económico, with some adjustments, particularly with respect to network distribution costs.

Two-thirds of this total represents expenditure in cruzeiros and a third foreign exchange expenditure. This distribution is similar to that for Chile, where the larger hydroelectric contribution to the programme, involving a smaller import component, counterbalances the lower level of self-sufficiency in capital goods in the electricity industry compared with Brazil.

On the basis of the actual gross product for the first three years of the period, and assuming a development rate of 5 per cent for the rest of the period and an investment coefficient of 15 per cent (as in 1959),

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investment in electricity would represent 6 per cent of the total. This sectoral coefficient for the period is lower than that for 1957-59, which was 8 per cent. This seems to show that unlike the other Latin American countries Brazil has already made a concentrated effort in electricity expansion, and this is demonstrated by the fact that at the end of 1959 projects under construction represented a total capacity of 4 million kW.

(c) Colombia

The investment required for the five-year period in order to attain an installed capacity of 1.6 million kW by 1965 is about 1,700 million pesos, of which 53 per cent represents the four main public service enterprises, 32 per cent Electroaguas and other government enterprises, and the rest self-suppliers.

Of the total amount, 55 per cent represents expenditure in local currency and the remainder foreign exchange expenditure.

If the gross national product, which in 1959 amounted to 23,000 million pesos, increases at the annual rate of 5 per cent, as postulated in the Four-Year Plan, the product for the five-year period 1961-65 would amount to 140,000 million pesos. If the coefficient of total gross investment remains at the 1959 level, electricity investment would constitute 7.3 per cent of total investment.

(d) Cuba

The investment envisaged in the electrification programme for the five years amounts to about 303 million pesos, of which 24 per cent represents generation, 31 per cent distribution and the rest substations and transmission lines. Two-thirds of the total cost represents imported materials.

With respect to unit costs, a figure of 35,500 pesos per kilometre is given for 110 kV transmission lines, and 109 pesos per kW for the generating plants. The last figure is low, even in view of the fact that it relates to fairly large thermal plants.

To appreciate the size of this sectoral investment in relative terms, it should be borne in mind that in order to achieve the annual growth rate of 13 per cent in the gross national product (excluding the sugar industry) assumed in the programme, the total product for the five years ending in 1965

/would amount

would amount to 17,300 million pesos. To this must be added the contribution of the sugar sector, with an estimated annual average production of 6 million tons at a price of 100 pesos a ton. Of the total of 20,300 million pesos, electricity investment would represent about 1.5 per cent of the product and, if the coefficient of total gross investment were 20 per cent, 7.5 per cent of that investment.

(e) Chile

Estimates by the Empresa Nacional de Electricidad, S.A. (ENDESA),6/ put its total investment for the decade, required to raise capacity from its present level to 1.4 million kW by 1970, at about 343 million dollars. Of this total one-third represents foreign exchange expenditure. It is envisaged that the Compañía Chilena de Electricidad (CCE), a subsidiary of American and Foreign Power, will invest between 200 and 250 million dollars, half of which would be in foreign currency. This investment represents the installation of the thermal plant at Renca, and another to be built somewhere in the coastal zone that lies between Valparaiso and Santiago, together with the expansion of the primary and secondary distribution networks. It should be noted that the CCE distributes and sells not only its own power, but also a sizable proportion of the power generated by ENDESA's hydro plants, which is transferred to CCE in block form.

The difference between ENDESA and CCE with respect to the import component of investment is mainly due to the fact that the ENDESA programme is over 95 per cent hydraulic, and the local currency element in such plants is naturally much higher because the civil engineering works constitute the major part of the total investment.

Thus the total cost of expanding the public service during the next decade will be about 543 million dollars, to increase installed capacity by 1.2 million kW, which represents a unit investment of 455 dollars per kW.

To this must be added the investment by the self-suppliers, particularly in copper mining, amounting to approximately 100 million dollars, at an

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6/ See the Electrification Plan approved by the ENDESA Board of Directors at their meeting on 26 November 1958.

estimated unit cost of 300 dollars per kW (since these plants are mainly thermal plants with short transmission lines and little investment in distribution).

Consequently total investment in the electricity sector would be about 650 million dollars, or 10 per cent of total investment, which has been estimated by the Corporación de Fomento de la Producción (CORFO) as 6,500 million dollars for the period under consideration. The total average cost would be 435 dollars per kW, and electricity investment would amount to at least two-thirds of investment under the heading of energy and fuel, which CORFO has estimated as 1,080 million dollars.

The high sectoral coefficient of investment for electricity in Chile compared with the average in the programmes of other Latin American countries (usually between 6 and 9 per cent) is due to the fact that the Chilean economy is characterized by its high specific consumption of electricity in relation to the gross product, and also, to a lesser extent, to the major part alloted to hydroelectric generation in the expansion programmes.

As in most Latin American countries, the responsibility of the government enterprise (in this case ENDESA) in the expansion of the public service capacity is greater than its actual share in that capacity. Consequently for a given rate of growth in total capacity, ENDESA must plan its future budget for a higher growth rate in its own capacity. The financial needs are thus out of proportion to real income, even on the assumption that the original rates were realistic and in line with costs.

As in the case of the Brazilian enterprises established in recent years, ENDESA, although in theory a mixed capital enterprise, is in practice a government body, although with a high degree of autonomy, since more than 99 per cent of the shares issued are owned by CORFO. This has the advantage of making possible the reinvestment of all profits, since the main shareholder is more interested in increasing the generating plant than in receiving dividends. On the other hand, this situation considerably reduces the possibilities of resorting to the private capital market for the purpose of attracting savings that are not being absorbed by other government bodies or by the national budget.

/(f) Mexico

(f) Mexico

The project programme of the Comisión Federal de Electricidad (CFE) envisages an addition of 3.3 million kW within the next five or six years, representing an investment of the order of 1,000 million dollars. To this must be added: (i) the investment proposed by the Compañía Mexicana de Luz y Fuerza (CMLF), estimated at 250 million dollars for the decade, which includes the improvements and expansions in the Sistema Central distribution networks; (ii) what CFE will invest in the years following on the completion of the aforementioned plan, and (iii) the expansion of the ex-Impulsora system, which will cost at least 100 million dollars for the decade; all this will add up to a total investment of the order of 2,000 million dollars, of which 75 per cent will represent generation and transmission, and the remaining 25 per cent distribution. As this investment represents a net additional capacity of 5.3 million kW, the unit cost of the expansion will be 380 dollars per kW.

The coefficient of investment in the Mexican economy, which averaged 14 per cent during the 1946-55 decade, has been slowly increasing in recent years, and in 1960 reached the level of about 16.5 per cent.

The gross national product at market prices amounted to 114,000 million pesos in 1958. On the assumption that the annual increment during the next ten years will be 5 per cent and the investment coefficient 17 per cent - slightly higher than that of 1960 -, total investment during the coming decade should reach 22,000 million dollars. Out of this total, investment in the electricity sector would account for 9 per cent. This sectoral coefficient confirms an observation applicable to all Latin American countries; the electricity expansion programme for the next ten years will entail a greater relative investment effort in the sector in question. It must be borne in mind that in fact, during 1946-55, Mexico invested no more than 5 per cent of its resources in electricity, although by the last three years of that period the proportion in question had attained 6.5 per cent.

(g) Peru

The investment contemplated in the 20-year plan formulated by the Electricité de France mission amounts to 14,300 million soles at the prices current on 1 January 1956; 45 per cent of this sum is allocated to the

/installation of

installation of generating plants, 18 per cent to high-tension transmission and the remaining 37 per cent to primary and secondary distribution networks. Thus, the average cost per installed kW would work out at about 6,000 soles, i.e. - at the rate of exchange in force at the same date (19.3 soles to the dollar) -, some 310 dollars per kW. Half this investment corresponds to expenditure abroad.

If the level of the gross national product in 1955 is taken as a base and an annual rate of increase of 5 per cent is assumed, together with a fixed gross investment coefficient of 20 per cent, the above-mentioned investment in the electricity sector represents, for the 20-year period under consideration, 7.5 per cent of total investment.

(h) Uruguay

A programme recently drawn up in Uruguay for electricity development during the next ten years 7/ recommends the investment of about 150 million dollars over that period, of which sum about two thirds would represent foreign exchange expenditure. Within this total, 63 per cent would be allocated to generation, 12 per cent to transmission and 25 per cent to distribution. It must be borne in mind that the percentage assigned to generation is relatively high in Uruguay, owing to the preponderance of hydroelectric energy and the cost of installing the corresponding plant, which is in the neighbourhood of 300 dollars per kW of guaranteed capacity.

In these circumstances, investment in the electricity sector would represent 8 per cent of the total investment required for Uruguay's economic development during the coming decade, estimated on the basis of a cumulative annual increment of 2 per cent in the gross per capita product and a population growth rate of 1.5 per cent.

(i) Venezuela

Venezuela's Four-Year Plan contemplates an annual increase in the gross product of about 7 per cent - a higher rate than that registered in 1958-60 (5 per cent), but lower than in the period prior to 1958. If, as is presupposed, the rapid rate of growth of the population decreases by 10 per

7/ See Hugo R. Giavi et al., La economicidad en la producción de electricidad (ST/ECLA/CONF.7/L.1.49).

/cent in

cent in relation to the level of 3 per cent at which it stood in the past two years, this would allow for a 4-per-cent annual rise in the per capita product. It is estimated that the mining and petroleum sector (iron mining in particular) will develop more slowly than the rest of the economy, so that its contribution to the gross product will fall from 29 per cent in 1958 to 24 per cent in 1964.

As regards the manufacturing sector, the increment projected is 12 per cent per annum.

In order to enable the Venezuelan economy to develop at this distinctly rapid rate, the intention is to invest 21,000 million bolivares during the four years covered by the Plan. If this net investment is added to the allocations covering depreciation of fixed capital, which represent something like 10 per cent of the total product, the resulting figure for total gross investment in the period in question (June 1960 - June 1964) is 36,600 million bolivares, or 23.4 per cent of the product during that lapse of time.

If the product is to increase at a rate of 7 per cent, an investment coefficient of 23 per cent ought to be attained. The projected product-capital ratio is, therefore, 0.3, or less than that estimated for other Latin American countries.

The possibility of raising the investment coefficient to so high a figure, completely out of reach of most of the countries of the region, is attributable to what has come to be called the policy of "sowing petroleum income". Thus, the following statement occurs in a message from the President of the Republic to the National Congress on 29 April 1960: "The State must shoulder the major responsibility for the satisfactory investment of petroleum income, which, characterized as it is by the exhaustibility of the source from which it derives, must be mainly used for the creation of new sources of revenue ... In the effort to secure better programming and an increased yield in the public sector, every endeavour has been made to see that the fiscal revenue accruing from petroleum is devoted entirely to development expenditure, so that the outlays relating to administration proper are covered by other income".

It is assumed that the investment level postulated in the Plan will be attained partly by means of a foreign capital contribution equivalent to

/2,400 million

2,400 million bolivares for the four years concerned, i.e., a little over 10 per cent of total capital formation requirements. The remainder will presumably be covered by public and private domestic saving. In view of import needs and the level of exports projected, approximately the same sum will probably be required to achieve balance-of-payments equilibrium in the period under consideration. Consequently, the limits to the rate of development set by the level of domestic saving and by the capacity for external payments are identical.

Such, in broad outline, are the basic objectives and hypotheses embodied in the Plan. The investment programmed in the electricity sector amounts to 1,050 million bolivares for the whole of the public service, two thirds of this sum representing the contribution of the State agencies. If the generating capacity installed by self-suppliers during the same period is approximately estimated to be a further 100 MW at an average cost of 300 dollars per kW, total investment in the sector should work out at 1,150 million bolivares - a sum which, in relation to a total net investment of 21,000 million, implies a sectoral coefficient of 5.5 per cent.

The fact that this value is lower than the corresponding figure for other programmes is explicable in view of the magnitude of the total investment coefficient. Even so, it is double the historical coefficient registered for 1950-59, when electricity investment accounted for only 2.8 per cent of total investment and 0.75 per cent of the gross national product.

As regards the public sector's investment, it is estimated that up to 1964 CADAFE will lay out some 420 million bolivares, one third of which will be spent on generating equipment, giving 254 additional MW (132 at Guanta, 75 at the Puerto Cabello expansion works and 47 MW at smaller plants). The remaining public investment will probably be allocated to the Caroní, where 250 million bolivares are to be earmarked for the Guri construction works. The final cost of the dam is provisionally estimated at 600 million bolivares, and would represent one third of that of the whole project, which, as was pointed out above, will permit the installation of about 4 million kW.

The cost of expanding installed capacity from the 1.3 million kW existing at the end of 1959 to the 3.8 million projected for 1970 may be estimated as in the neighbourhood of 1,100 million dollars. This calculation

/is fundamentally

is fundamentally based on the projections formulated by Electricité de France, for the CADAFE and Caroní programme, on the hypothesis that Guri and Caracas will be interconnected before the end of the decade; to the values thus obtained is added that of the expansion of the Caracas plant up to the date of interconnexion and the estimated investment of self-suppliers.

If the foregoing figure is compared with that corresponding to the period covered by the Four-Year Plan, the resulting inference would seem to be that the financial effort will be greater in the second half of the decade and that the coefficient of the sectoral distribution of investment for the electricity sector will possibly have to be increased. This is logical enough, since the projects for the said period comprise the biggest hydroelectric engineering works and the integration of the national network, all of which calls for relatively substantial investment.

Chapter II

CRITICAL ANALYSIS OF ELECTRICITY EXPANSION PROGRAMMES

There now follows a fairly detailed analysis, based on the data available in each case, of a series of fifteen countries comprising 96 per cent of installed capacity and 98 per cent of electric power production in 1959.

Special attention is devoted to the group constituted by the five leading producers (Brazil, Argentina, Mexico, Venezuela and Chile, in descending order of installed capacity at the end of 1959), which account for three fourths of Latin America's installed capacity and four fifths of the energy generated in the region. The following is a detailed break-down:

Country	Installed capacity in 1959 (Millions of kW)	Generation in 1959 (Thousands of millions of kWh)	Degree of utilization (Hours/year)
Brazil	3.9	21.1	5,400
Argentina	3.0	9.8	3,200
Mexico	2.7	9.8	3,600
Venezuela	1.3	4.3	3,300
Chile	1.1	4.6	4,200

It will be noted that, owing to the marked disparities between degrees of utilization, the order of the installed capacity column differs from that of the generation column. Thus, Mexico, although its installed capacity is less than Argentina's, generated the same amount of electricity, and Chile's inferiority to Venezuela in respect of installed capacity was easily offset by its higher level of production.

In order to compare, even if only approximately, the expansion programmes adopted or recommended in the main countries of the region with the installed capacity requirements deriving from the various projections and forecasts formulated, table 6 was prepared on the following basis:

/1. Column

1. Column P (1959) gives each country's total installed capacity at the end of 1959;

2. Column P_1 represents the installed capacity needed if the generation requirements resulting from extrapolation of the 1950-59 trend are to be satisfied in 1965. The same degrees of utilization as in 1959 were adopted, as it was felt that possible improvements might be offset by the necessary increases in the present narrow margins of reserve;

3. Columns P_2 - P_3 and P_4 indicate the installed capacity determined by these countries' generation requirements in accordance with different economic development hypotheses. P_2 - P_3 represent the two extremes corresponding to the "minimum" and "maximum" hypotheses, and P_4 the "intermediate" hypothesis;

4. Column P_5 presents the projection of installed capacity for the year in question which is adopted in the relevant electricity development programme.

An attempt will now be made to summarize the interesting inferences which may be drawn from an analysis of the figures appearing in table 6. In the first place, as regards the third and fourth columns, the anomalies already discussed in connexion with the projections of energy generation for various rates of economic development reappear in the cases of Argentina and Brazil, as is to be expected; nothing further will therefore be said on this point.

To judge from a comparison of the second and fifth columns, two of the countries apparently have expansion programmes that would prove relatively inadequate to satisfy a rate of electricity development such as that registered in the past five years, which in general would seem to be a minimum requisite. This is not so, however, in the case of Venezuela, since the rate of growth of demand in the five-year period 1955-59 (like that of the gross product) was exceptionally high and is unlikely to recur, as the experience of 1960 and 1961 is already testifying. The fact that the same argument is not valid for Argentina reaffirms the conclusion reached when that country's individual case was discussed, i.e., that an attempt should be made to tackle a more ambitious electricity programme, better suited to the level of development that needs to be reached during the next few years.

/Table 6

Table 6

LATIN AMERICA: COMPARISON OF INSTALLED CAPACITY IN SELECTED COUNTRIES

(Millions of kilowatts)

Country	P(1959)	P_1	P_2-P_3	P_4	P_5
		1965			
Brazil	3.9	7.3	4.8-6	5.1	8
Argentina	3.0	4.7	7.2-9.1	7.7	4
Mexico	2.7	4.4	3.7-4.8	4.0	5.5
Venezuela	1.3	3.1	2.7-3.2	2.9	2.2
Chile	1.1	1.4	1.5-1.7	1.6	1.7
		1970			
Brazil	3.9	12.0	6.2-8.7	7.0	14.0
Argentina	3.0	6.6	11.6-21.2	15.4	5.5
Mexico	2.7	6.7	5.1-7.2	5.7	8.0
Venezuela	1.3	6.4	5.4-7.8	6.0	3.8
Chile	1.1	1.8	1.9-2.5	2.1	2.6

/According to

According to the programmes analysed for the various countries, about 60 per cent of the additional capacity will be hydroelectric. The present slight preponderance of hydroelectricity will thus be intensified. The extent to which this preponderance increases will depend principally upon the decisions taken by Argentina in relation to the El Chocón project and by Argentina and Uruguay with respect to Salto Grande; developments in this connexion will determine what proportion of the total, within a range of 55 to 62 per cent, will be represented by hydroelectric capacity at the end of the next decade.

It is of interest, in view of the change or evolution signified thereby in recent years, to note the absence of nuclear power stations in the expansion programme for the decade, except in the case of Brazil. Latin America is thus no exception to the almost universal rule that in practice the construction of power stations of this type is falling short of the over-optimistic forecasts of five or six years back.

This does not mean that the study of such possibilities has been abandoned; on the contrary, most State agencies dealing with electricity planning avail themselves of the services of technical specialists in this field, who carefully follow the course of events in the developed countries, especially with respect to trends in installation costs and the comparative advantages of the different types of reactors. At the same time, tentative projects are being prepared, as well as a programme for the training of technical personnel, especially at the higher levels.

In Latin America there are many places and areas where the prevalence of high fuel oil supply costs and either heavy hydroelectricity costs or shortage of water resources might mean that the generation of nuclear energy would prove an economic proposition, even though it might not be so in areas which are easy of access or rich in water resources. Again, the fact that in serveral compact areas the volume of demand is already very large permits the inclusion of nuclear units of 150,200 MW, or even more, in some systems, with the certainty of their optimum utilization.

/In this

In this context, it may be remarked that while nuclear power more clearly resembles the conventional thermal type as regards technical generation characteristics and occupation of the centre of the load diagram, it also displays analogies with hydro power in respect of the heavier unit investment required and its slighter repercussion on the balance of payments, since in both cases the high initial investment needed is offset by low operational costs and, in particular, a saving of inputs from external sources if fuel has to be imported.

In the annex, certain considerations are formulated with respect to the comparative analysis of a nuclear power station and another of the conventional thermal type, which illustrates the influence of the main parameters of the problem.

1. Argentina

In 1959, generation of electric energy amounted to 9,800 million kWh, with an installed capacity of 3 million kW, three fourths of which represented the share of the public service. The high percentage of generation by self-suppliers is not warranted, as it is in other countries, by the geographical distribution and the structure of the production system. On the contrary, the generation of electricity by self-suppliers is split up among a large number of small plants scattered over the self-same area as is served by the public utility installations, with the consequent anti-economic situation deriving from the extra cost of current inputs and capital formation. Consequently, the transfer to the public service sector of a substantial part of the demand at present met by self-suppliers ought to constitute one of the chief targets of any electricity programme devised for Argentina; some of the problems involved in respect of analysis and the adoption of decisions have already been touched upon in the first part of the present study.

A second and equally important organic defect in Argentina's electricity system is the low proportion of hydroelectricity (7.5 per cent of total installed capacity), despite the availability of sufficient water resources not only for the generation of electricity but also for multiple-purpose projects.

/A third

A third target must be the modernization of total installed thermal capacity, with a view to the reduction of the present high specific consumption of fuels and the improvement and expansion of the distribution networks so as to lower the current level of losses, which is as high as about 19 per cent of the plant load.

In connexion with the second point, it should be pointed out that, as regards the structure of Argentina's aggregate generating capacity, the Greater Buenos Aires - Litoral and Resistencia - Corrientes areas differ substantially from the rest of the country, inasmuch as their generating plants are all thermal, whereas elsewhere in Argentina 60 per cent of installed capacity is hydroelectric.

The three main targets mentioned above were incorporated in the programme prepared by ECLA for 1955-67; but the projections on which it was based, so far at any rate, have not come very near the truth, partly because the hypotheses adopted with respect to the rate of development of the product and the tempo of industrialization have not been borne out by the facts, and partly because the recommended programme of works has not been put into effect. In contrast, investment in the electricity sector has continued to be insufficient, not merely to support a policy aiming at the promotion of consumption or the gradual limitation of generation by self-suppliers, but even to reduce the considerable installed capacity deficit which already existed at the date when the projections were formulated.

With respect to the inadequacy of the development which actually took place in the five-year period 1955-59 as compared with the targets established in the study referred to, suffice it to say that the gross product increased at a rate equivalent to the growth rate of the population (in other words, the gross per capita product remained stationary), which meant that it rose by about 2.8 per cent yearly, whereas the target proposed was 6.5 per cent. For the expansion of the industrial sector the target was 8 per cent; the real increment during the quinquennium represented less than half that figure.

/As regards

As regards the extent to which the projects have fallen behind schedule, the present status of those recommended by ECLA in 1955 may be analysed as follows: (a) it was assumed that the CADE and CIABE expansion works, totalling 370 MW, would be completed by 1961, whereas only one third of that capacity will have been brought into service at the date contemplated; (b) another assumption was that the 600 MW at Dock Sud would be ready by 1961-62, whereas this will only just be possible by 1964-65, always providing that a solution is found for financial difficulties that are still pending; (c) it was taken for granted that construction of the Chocón hydroelectric power station would begin in 1959 and that the plant would enter operation in 1963, but the works in question have in fact not even been contracted for; (d) in the case of Salto Grande, it was assumed that construction would begin in 1960 and end in 1965. It is actually only a few months since the contract was drawn up for the preparation of a preliminary project with a view to inviting tenders, and nothing is known of how the project is to be financed. It seems reasonable to assume, therefore, that even if the governments of the two countries concerned are determined to proceed with the execution of the project (there are important problems connected with the distribution of the energy generated during the first few years, on which negotiations will have to be conducted), construction cannot begin earlier than 1963 nor the plant be brought into service before 1968.

An analogous example is afforded by the Electrification Programme (Programa de Equipamiento Eléctrico) for 1955-65, which was prepared by the National Power Department (Dirección Nacional de la Energía) and contemplated the installation of 3,500 MW by 1965. Barely one third of this additional capacity will be attained. Prior to January 1963, the entry into operation of the additional 140 MW at Puerto Nuevo (SEGBA) and of the first group (120 MW) at the Nueva Dock Sud plant is all that can be expected. To sum up, then, the programmes suggested for Argentina have been implemented only to a minimum extent.

/(a) The

(a) The consultants' report

In June 1960 the United Kingdom and United States firms of consultants contracted by the Government of Argentina and the International Bank for Reconstruction and Development, with assistance from the United Nations Special Fund, to carry out a study of the electricity situation in Argentina, presented a report whose substance will be analysed here because it has so direct a bearing upon the theme of the present study.

The report in question relates to electric power requirements in six areas in Argentina during 1960-69. These areas are the following:

I. Greater Buenos Aires-Litoral
II. Córdoba
III. Mendoza
IV. Tucuman
V. Upper Valley of the Río Negro
VI. Resistencia-Corrientes

Out of the total energy generated by the public service in 1959 (7,500 million kWh) these six areas accounted for 92 per cent; the proportion of total installed capacity which they represented was somewhat smaller - 82 per cent. The Greater Buenos Aires-Litoral area alone absorbed 80 per cent of total demand for power, which was equivalent to 86 per cent of aggregate demand in the areas covered by the study.

The conclusions formulated in the report may be summed up as follows:

(i) Generation of energy by the public service in the six areas will increase during the eleven-year period 1958-69 from 6,300 to 14,000 million kWh;

(ii) An additional generating capacity of 2.2 million kW will need to be installed in the areas in question, of which 84 per cent will have to be thermal and the remainder hydroelectric. In areas I and VI the systems will continue to be purely thermal and the major addition in respect of hydroelectricity (128 MW) will correspond to the Mendoza area. The aim will be to double existing generating capacity in the next nine years;

/(iii) As

(iii) As regards transmission, it is proposed to construct some 1,700 kilometres of lines at 132 kV and 1,200 kilometres of lines at 66 kV;

(iv) Total investment will probably be as follows:

	Value (Millions of dollars)	Percentage of total
Generation	337	45.8
Transmission	126	17.2
Distribution	272	37.0
Total	735	100.0

The relatively small allocation for transmission lines is explained by the fact that the programme excludes large-scale hydroelectric works like Chocón and Salto Grande, the postponement of which is recommended, although for different reasons in each case.

The rate adopted for the conversion of local expenditure into foreign currency is 80 Argentine pesos to the dollar. As far as generation and transmission are concerned, funds in foreign currency are estimated to represent 55 per cent of the total. For investment in distribution networks the proportion falls to 23 per cent. Hence total foreign exchange requirements will work out at 318 million dollars.

The Salto Grande power station, with 770 installed MW (i.e., Argentina's share, which is half of the total), would cost - with the inclusion of the transmission lines to the Buenos Aires-Litoral system - 97.5 million dollars more than the equivalent thermal capacity. According to estimates, the gross annual profit on this additional investment would average 13.2 per cent. Even if it is recognized that the average cost of capital, in real terms, will be less than this figure and that consequently the project is economically justifiable, the consultants advise its postponement because of the scarcity of short-term capital.

Chocón, with 900 MW of installed capacity, would cost 134 million dollars more than the equivalent thermal capacity, and the average annual profit on that investment would only be 6.2 per cent. If Chocón is to

/produce lower-cost

produce lower-cost power, according to the report in question, part of the cost of the works will have to be allocated to other benefits such as flood control and irrigation.1/

If Salto Grande and Chocón were to supersede the equivalent thermal plants (715 MW in the case of Chocón and 600 in that of Salto Grande), the capacity to be installed in 1960-69 would total 2,584 MW (1,863 hydroelectric MW plus 721 thermal). The total cost of this programme would be 966 million dollars.

It should be noted that while this alternative programme would solve Argentina's electricity problem for 1969-70, it does not, on the other hand, represent a real alternative for the intervening years, since, even in the most favourable circumstances, neither of the two big hydroelectric projects could begin to deliver power to the Greater Buenos Aires area earlier than the winter of 1968, and, obviously, more than 721 MW will need to be added to the inadequate existing capacity some long while before that date.

It would therefore seem advisable, if the decision is taken to increase hydroelectric capacity, for only one of the two projects to be undertaken straight away as a substitute for the equivalent thermal capacity in the programme recommended by the consultants.

To judge from their analysis, the Salto Grande project seems to be considered preferable. It should be pointed out in this context that given Uruguay's lower level of consumption, it would be several years before this latter country could absorb its production quota, and in that case it would seem reasonable for Argentina to purchase the available surplus on terms agreed upon between the two countries.

While this consideration makes the project more attractive from Argentina's point of view, it might have disadvantageous implications for Uruguay, since this country would have to invest a great deal of capital that would begin to yield profits only on a long-term basis. This inequality in the position of the two countries (apart from the problems which would

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1/ According to an ECLA study, the Chocón project already included these benefits.

/derive from

derive from the possible substitution - even if it were partial and temporary - of the hydro power generated by the Salto Grande plant for the thermal generation of the Buenos Aires power stations, in view of the complicated institutional structure of Argentina's aggregate installed capacity) would necessitate a careful study of the financial aspects of the project, another factor which would tend to lengthen the period required for its execution.

(b) Critical analysis of hypotheses and projections

Comparisons between hydroelectric and thermal projects were based, logically enough, on the systems studied in each case, since there would have been no point in making a separate analysis of each power station.

For the purpose of calculating the initial cost of the projects, interest payable up to the end of the period estimated for construction was added to the capital required. The interest in question was computed at rates of 6 per cent on foreign exchange expenditure and 9 per cent on expenditure in local currency.

Depreciation charges were estimated by the linear method and on the basis of the following table of useful life:

	Years
Civil engineering works at hydroelectric power stations	100
Mechanical and electrical installations at hydroelectric power stations	35
Thermal power stations, including civil engineering works	25
Transmission lines	30
Sub-stations, including civil engineering works	25

As regards fuel inputs, at the suggestion of the committee under whose direction the study was carried out, the consultants adopted the following local currency prices per million calories for fuel delivered at Buenos Aires:

	Argentine currency	Dollars (at 80 Argentine pesos to the dollar)
Coal	190-198	2.38 - 2.46
Fuel oil	155.3	1.94
Natural gas	145.6	1.81

/As regards

As regards demand for power in the market areas studied, projections were formulated on the following bases: (a) research on past consumption trends, as indicated by available statistics and an estimate of generation by self-suppliers; (b) analysis of the possible future trend of consumption, classified under four main heads: household, commercial, industrial and official (street lighting, transport, etc.). This analysis was based on an extrapolation of historical trends with the necessary adjustments for the estimate of unsatisfied demand and for annual growth rates of 4.5 per cent in the case of the gross produce and 7 per cent in that of industry; (c) where circumstances rendered it advisable, special studies were carried out on the probable demand of selected activities, such as irrigation by pumping, petroleum production and industries with a high level of electricity consumption.

It was thus calculated that by 1969 the generation of electricity required in the areas in question would amount to 14,000 million kWh; if the proportion in relation to the rest of the country remained the same, total public utility generation requirements would reach 15,200 million kWh.

Without detailed consideration of the bases on which the consultants prepared their estimates, it would seem that this aggregate result seriously underrates the country's real requirements. It should be noted that the generation of 15,200 million kWh signifies a 100-per-cent increment in the ten years subsequent to 1959, when, as was stated at the outset, the corresponding figure was 7,500 million.

Can a growth rate of barely 7 per cent be considered satisfactory for public utility generation, when the gross product would increase by 4.5 per cent, when there is at the present time a great deal of unsatisfied demand owing to supply restrictions extending over several years, and when most of the programmes for the other Latin American countries estimate that generation and installed capacity will be more than doubled, and in many instances trebled, in the course of the coming decade?

How can it be supposed, moreover, that so low a rate of expansion of public-utility generation would suffice not only to meet the growth of demand but also to permit the gradual replacement of generation by self-suppliers, which at present constitutes an economic burden?

/This is

This is of course reflected in an unduly modest target for the exapnsion of capacity, which the consultants estimate at 2.2 million kW.[2/] Despite the more efficient plant utilization thus contemplated, the 70-per-cent increase referred to is from every point of view lower than real requirements, which will possibly entail at least the duplication of existing installed capacity. Such an addition, for the reasons already given, will have to be effected almost entirely in the public utility sector.

An increment in the neighbourhood of 2 million kW would be compatible only with a prolongation of the economic stagnation of recent years, or with the persistence and even the intensification of the tendency for self-suppliers to install generating plant that represents a heavy burden on the national economy, since the lack of suitable reserves in the existing public-utility system in the main consumer centres leaves but a narrow margin for the absorption of new demand.

2. Brazil

Despite Brazil's importance within the economic system of Latin America and, in particular, its electricity sector, which represents one fourth of the region's total installed capacity, only brief reference will be made to its expansion programmes for the coming decade, since several other studies submitted for consideration at the present Seminar deal with the same topic.[3/]

In the Programme of Targets (Programa de Metas), formulated for the first time in 1956, the objective indicated was that the existing 3 million kW should be increased to 5 million by 1960, an aim which has gradually been

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2/ It should be noted that according to the report under consideration the percentage increase would work out at a higher figure for generation than for capacity, which seems unlikely in view of the fact that with the reserve projected - approximately 15 per cent - restrictions would disappear; this would mean that the load factor would tend to diminish rather than to increase.

3/ See Carlos Berenhauser Jr., A Energia Elétrica no Brasil - Aspectos Gerais (ST/ECLA/CONF.7/L.1.03); Mario Penna Behring, Financing the expansion of electric power supply in the State of Minas Gerais (ST/ECLA/CONF.7/L.1.36); Antonio José Alves de Souza, Companhia Hidro Elétrica do São Francisco (ST/ECLA/CONF.7/L.2.20).

/fulfilled, although

fulfilled, although with a certain time-lag (by the end of 1959 there were about 4 million kW). If the implementation of the programme were to continue on relatively normal lines up to 1965 - which seems feasible in view of the favourable experience of the first four years and the works already in the advanced or initial stages of construction -, by the end of that year installed capacity will slightly exceed 8 million kW.

Should the demand trend registered in the past decade be maintained, supply requirements for 1970 will amount to 14 million kW; in other words, 6 million kW will have to be incorporated into the system between 1965 and 1970, thus doubling the increase projected for the preceding five-year period, i.e., 1960-65.

Among the new power stations (or significant expansions of plants already in existence) which will presumably be brought into service by 1966, the following are of outstanding importance: Furnas (1,200 MW), Tres Marias (520 MW), Peixoto (400 MW) and Paulo Alfonso (390 MW), all hydro-electric; and Cubatao (390 MW) and Piratininga (250 MW), both thermal.

Thus, more than two thirds of the capacity to be installed will be hydroelectric so that the present predominance of hydraulic generation in Brazil will be maintained.

Of salient importance in the electricity map of Brazil is the area known as the Regias Cento-Sul.[4/] Comprising as it does the States of São Paulo and Río de Janeiro, the Federal District, the north-eastern part of the State of Paraná, the centre-south of the State of Minas Gerais and the southern zone of the State of Espiritu Santo, it represents 8.8 per cent of the whole area of the country and contains 42 per cent of the total population. But in the electricity sector its significance is much greater, inasmuch as it reflects a per capita income and productivity which are a good deal higher than the average for the country; the installed electricity potential is in the neighbourhood of four fifths of the total for Brazil.

4/ For a more detailed analysis of some of the points referred to here, see Mario Lopes Leao, O suprimento de energia elétrica a Regiao Centro-Sul e o problema da interligaçao dos grandes sistemas elétricos existentes, an address delivered at the Instituto Eletrotecnico de Itajubá, on 12 October, 1958.

/The accompanying

The accompanying diagram shows the relative geographical position of the three major consumer centres in the area, namely, São Paulo, Rio de Janeiro and Belo Horizonte, with their respective peak loads in 1959. The diagram also indicates the position of the secondary centre (centre of gravity) of the said main load triangle, as well as the situation of the Furnas and Tres Marias hydroelectric power stations, which will serve the area in the future.

In the Regiao Centro-Sul the following systems operate:

(a) The Grupo Light (Brazilian Traction), consisting of the São Paulo Light Serviço de Eletricidade and its associate the Companhia Carris Luz e Força do Rio de Janeiro, which, although operating with different frequencies (60 and 50 cycles respectively), are interconnected by a 230-kV line whose transmission capacity is limited to 200 MW, owing to stability problems.

The Grupo Light accounted for three fourths of the area's installed capacity in 1959, but this proportion will gradually decrease with the entry into service of the three big hydroelectric power stations in the zone. 5/

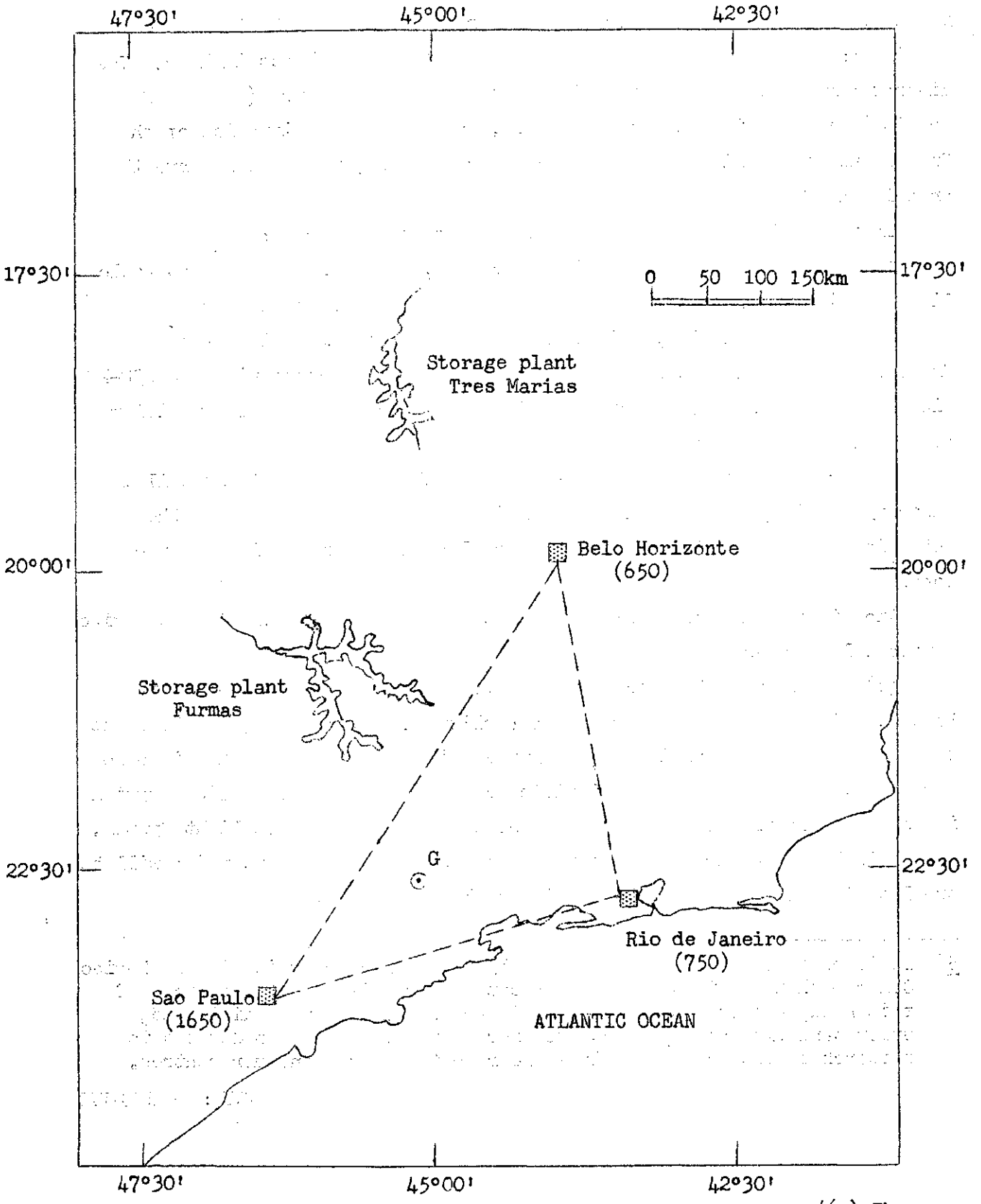
Rio Light is the only important system of those operating in the Regiao Centro-Sul which has a generation frequency of 50 cycles.

(b) The Empresas Electricas Brasileiras group (American and Foreign Power), which comprises the Companhia Paulista de Força e Luz, in the State of São Paulo, the Companhia Força e Luz de Minas Gerais, operating in Belo Horizonte, and others of less significance. The Companhia Paulista system is somewhat unsatisfactorily interconnected with the Campinas Light System.

This latter comprises about 220 MW of installed capacity, which will be trebled with the addition of the Peixoto plant's 400 MW.

5/ It is of interest to note that the hydroelectric potential in the Regiao Centro-Sul is estimated at 60 per cent of Brazil's total resources of this kind, although this estimate is presumably somewhat distorted, understandably enough, since much more attention has been devoted to research on resources relatively near to the large consumer centres.

BRAZIL : PRINCIPAL LOAD TRIANGLE IN THE CENTRE-SOUTH AREA



/(c) The

(c) The Centrais Eletricas de Minas Gerais (CEMIG) system, which operates in the State of the same name, at present possesses 250 MW and has expansion plans which will bring this figure up to 1,350 MW in the course of the coming decade. CEMIG was organized in 1951 as a joint stock company with a preponderance of State capital but open to the participation of private capital, although the proportion of shares held by this latter is extremely small.

(d) The USELPA-CHERP system, in the State of São Paulo, which covers the areas served by the hydroelectric plants on the rivers Paranapanema and Pardo. According to estimates, by 1965 the aggregate installed capacity of the two systems will amount to about 700 MG, although only the first has a potential of more than a million kW. The policy of the State authorities consists in constructing a system of power stations on the basis of integrated utilization of water resources and delivering the energy en bloc for distribution by the concessionaries operating in the State.

To these four groups or systems will be added, in the course of the next five years, a separate joint stock company - already formed but not yet producing energy - called the Central Eletrica de Furnas S.A., controlled by the Federal Government and including among its principal shareholders the São Paulo Light, the State of São Paulo through the Companhia Hidroeletrica do Rio Pardo (CHERP) and the State of Minas Gerais through CEMIG. The construction of the Furnas works was begun in 1958, and it is expected that the first stage, which consists of four units of 137 MW each, will be brought into service by the end of 1963. Power will be delivered at at 138 kV in the reducer substations which will interconnect the Furnas high-voltage network with the networks of São Paulo Light, CHERP and CEMIG. Half the output of Furnas will be delivered en bloc to CEMIG for distribution within its network, and the other half to São Paulo Light and CHERP.

From this brief analysis it can be clearly seen that the Região Centro-Sul offers particularly suitable conditions for exploiting the benefits of an interconnected network of generator and consumer centres with a central load distributing plant. This will mean that optimum advantage will be taken of the diversity of the consumer load diagrams, the heterogeneity

/of the

of the river régimes and the economies of scale deriving from the concentration of capacity in large units.

In this respect, the creation of the Furnas company is a considerable step forward for it combines the main electricity groups which will have to co-ordinate the interconnected system in such a way as to ensure its optimum operation.

In 1966, the area will have some 6 million kW out of the estimated total of 8 million for the whole country. Operation will be the responsibility of: the Grupo Light (which will have to standardize its frequency) with some 2.5 million kW, Furnas with 1.2, CEMIG with 0.8 million (including the 520 MW of Tres Marias), and the Grupos EEB (American and Foreign Power Inc.) and USELPA-CHERP (State of São Paulo) with 700 MW each.

Other projects on which construction work has been started and which are worthy of mention, include:

(a) The nuclear power station of Mambucaba at the mouth of the river of the same name, which will have between 150 and 200 MW. This power station will be interconnected with the system of the Centre-South area which already has more than four million kW of installed capacity, and this will mean that the Mambucaba plant can be used with a high plant factor. (See the annex.)

(b) The hydroelectric utilization of Urubupungá on the Paraná river where the construction of the first stage has already begun. This first stage will be the Jupiá power station with 1.3 million kW. For the construction of these hydroelectric works a public company has been formed named Centrais Eletricas de Urubupungá S.A. (CELUSA). The shares in the Company are jointly owned by the States of São Paulo - the largest single shareholder and consumer of electric power - Paraná, Santa Catarina, Goiás Mato Grosso, Minas Gerais and Rio Grande do Sul. The installed capacity to be finally established at Urubupungá will be 3 million kW.

The first stage of Jupiá involves an investment estimated at 15,600 million cruzeiros at 1961 prices. The plant will operate with twelve generator groups of 100 MW each and the first groups will start producing in 1966-67.

/(c) The

(c) The electrification plan for the north-east prepared by the Companhia Hidro Eletrica do Sao Francisco (CHESF), in co-operation with the Conselho de Desenvolvimento do Nordeste (CODENO). The first stage will be the hydroelectric plant of Paulo Alfonso which will by 1965 have an installed capacity of 390 MW.

(d) The electrification plan of Rio Grande do Sul which, if completed normally, will make it possible to triple present installed capacity of about 200 MW by 1966.

In Brazil as in the rest of Latin America, there has been a fall in the percentage of power generated by private companies and in particular by foreign companies. In 1955, the Grupo Light with 1.6 million kW and the Brazilian subsidiaries of the American and Foreign Power Company Inc. with 0.4 million kW together accounted for about two thirds of total installed capacity in the country. On the basis of events over the last five years and proposals for the next five years this share will in 1965 have been reduced to scarcely more than a third. The proportions as regards power dispatched for final consumption will, however, be somewhat different from those just mentioned and closer to the figures for 1960, since some of the largest publicly financed power stations in the Centre-South area will supply power in block and at high tension to the privately-owned companies, who will be responsible for final distribution.

State financing in the 1955-65 decade will lead to increases three times greater than for private companies, since during that period, totally or predominantly State-owned undertakings will install 3.4 million kW, while private companies will install only 1.2 million kW.

This means that the financial problems of the State-owned concerns are much more serious, for while their present share in the total amount of power sold is less than half, they must in the next five years install three quarters of the total amount of new capacity. The result is that a rates system which might give private concerns adequate returns to finance their own expansion programmes, will prove totally insufficient for the State concerns which will, accordingly, have to turn to other sources of finance.

/3. Central

3. Central America and Panama

At the end of 1959, the total installed capacity of these six countries was 430 MW, four fifths of which were in the hands of public service undertakings. The public service for its part with half its capacity consisting of hydroelectric facilities (which, however, owing to a more efficient degree of utilization generated three quarters of total power)produced, in 1959, 1,135 million kWh which were sold in the area for 32 million dollars.

It should not be forgotten that although these countries have been grouped together for reasons of statistical convenience and geographical proximity, there exist profound differences between them. In the electricity sector, as in other sectors, heterogeneity is very great, both as regards generation and consumption and as regards the structure of the generating plant or the various tariffs in force. For example, per capita public service installed capacity in Costa Rica, with a per capita figure of 90 Watts, is ten times higher than in Honduras. In El Salvador and Costa Rica more than 90 per cent of power is generated hydroelectrically; the exact opposite occurs in Nicaragua and Panamá.

The relationship between Costa Rica and Honduras as regards total installed capacity is reversed for average sales tariffs. Honduras, which charges 8 cents of a dollar per kWh, applies rates five times higher than does Costa Rica.

In estimating generating capacity and the investments required for the next ten years, we have in some cases used as a basis for the programmes drawn up by official agencies in the countries concerned. This is what occurred in Costa Rica, while in Honduras and El Salvador, for example, recourse was had to private consulting agencies.

These programmes show that the satisfactory development of electricity services in the area will require the addition over the next ten years of some 500 MW. It is assumed that 90 per cent of the additional capacity will be operated by public service undertakings and these will thus increase their participation in the electricity sector, thereby continuing the trend of the previous decade and following the course of events in the rest of Latin America.

/4. Colombia

4. Colombia

Total generation in 1959 was 3,300 million kWh, 81 per cent of which was provided by public service undertakings. At the end of 1959, the installed capacity available for generating that amount of power was 865 MW, 58 per cent of which was hydroelectric, 22 per cent thermal or steam, and the remaining 20 per cent was produced by internal combustion units.

The public service had an installed capacity of 635 MW, 72 per cent of which was hydroelectric.

The four main public service undertakings [6/] represented 70 per cent of installed public service capacity and 80 per cent of the power generated by the public service sector, their respective share of installed capacity being 22 per cent, 20 per cent, 14 per cent and 14 per cent.

We shall now analyse the demand projections and expansion programmes of the electricity sector using as a basis the information contained in the Colombian Government's Four-Year National Public Investment Plan (1961-64).

For reasons of simplicity we shall divide electricity producing undertakings into three groups, including:

Group I: Systems belonging to the electricity undertakings of Medellín and Bogotá, the CVC and the Compañía Colombiana de Electricidad;

Group II: Subsidiaries of the Instituto de Aprovechamiento de Aguas y Fomento Eléctrico (Electroaguas) and other public systems;

Group III: Self-suppliers.

6/ These are, in order of size: La Empresa Pública de Medellín, La Empresa de Energía Eléctrica de Bogotá, La Compañía Colombiana de Electricidad (subsidiary of the American and Foreign Power Company Inc.) and La Corporación del Valle del Cauca (Cali).

/The expansion

The expansion plans of the four undertakings in Group I include the installation of some 400 MW by the end of 1965, four fifths of which are to be hydroelectric, while the estimated additional capacity to be installed by self-suppliers is 80 MW. As to Electroaguas, the Four-Year Plan provides for the installation of 208 MW and in 1965 of a further 26 MW, or a total of 234 MW.

Installed capacity in 1965 will accordingly be approximately 1.6 million kW or about 300 MW lower than the level which Colombian planners consider should be available in that year to generate the 7,000 million kWh which demand will require. The calculation of demand at such a level corresponds to an annual rate of increase in generation between 1958 and 1965 of 13.1 per cent deriving from the target for annual increases in gross domestic product, which is 5 per cent.

It should be noted that these targets coincide with those set forth in the Electrification Plan of March 1955. That Plan also provided for an annual cumulative rate of growth of 13.1 per cent which implied a level of electricity generation for 1965 of the order of 7,000 million kWh. On this basis and supposing an equal degree of utilization of hydraulic and thermal plants, the plan recommended that installed capacity in 1965 should be 1.8 million kW, one quarter of which would be thermal and the rest hydroelectric.

These forecasts were not in fact fulfilled, partly because the rate of development of the Colombian economy, as occurred in the majority of countries in the area, was lower in the five-year period 1955-59 than in the immediately preceding period which had served as a basis in the preparation of the projections; and also partly because of the scarcity of available resources to increase the rate of capital formation in the electricity sector.

Both factors are in their turn related to each other by virtue of fluctuations in the purchasing power of exports and the influence which this is known to have on savings and investment levels. For example, gross capital formation, which had in 1955 been almost 27 per cent of gross product, had in 1959 fallen to less than 17 per cent.

/It is

It is not therefore surprising that the rate of growth of product should have declined by half.

As to electricity generation, the growth rate in 1955-59 was 10.2 per cent or slightly less than for the preceding decade. This is the same rate of growth as that mentioned in the Four-Year Plan as being likely to continue during the period 1965-70, thus achieving a figure for generation of 12,000 million kWh and an installed capacity required for such generation of 3.1 million kW.

5. Cuba

At the end of 1959, Cuba had an installed capacity of 932 MW, 58.5 per cent of which was in the hands of public service undertakings (among these a predominant part is played by the Compañía Cubana de Electricidad which accounts for 94 per cent of the public service) and the remaining 41.5 per cent corresponded to self-suppliers. Among the latter, particular attention should be drawn, by reason both of their importance and their special characteristics, to the sugar industry generating plants with a total installed capacity of 311 MW or 82 per cent of the installed capacity of self-suppliers.

The degree of utilization is substantially higher in public service undertakings (3,840 hours in 1959) than among self-suppliers (1,900 hours). Apart from the special characteristics of the sugar industry which partly account for the low degree of utilization of its electricity capacity, it should be pointed out that there is considerable idle capacity, this being the reason why the sugar sector was excluded from the projections made by the Sectoral Programming Department of the Central Planning Board on which we have based our analysis.

The electricity development programme for Cuba must meet various basic targets, including:

(a) Extension of installed capacity in order to meet the demand that a satisfactory level of economic development requires. It should be pointed out that government plans provide for an acceleration of the rate of economic development, and this would involve an increase in electricity demand at a higher rate than during the six-year period 1953-59 when the rate was 9 per cent.

/(b) The

(b) The improvement and extension of transmission networks as a first step towards the interconnexion of the electricity systems of the West and East in a national network, with all the benefits that this would imply for the country.

(c) The reduction of high specific consumption of fuels in thermal generating stations. This is of great importance in Cuba owing to the small percentage of power generated hydroelectrically and the almost total lack of development of the country's petroleum resources.

Such an improvement in efficiency is necessary not only in the public service generating stations which operate on fuel oil but also in the generating unit of the sugar mills which work mainly on bagasse. This is not of any great importance at the present time, since there is an excess of bagasse in relation to the fuel needs of the sugar mills themselves and to the requirements of other industries (paper, cardboard, etc.) which at present represent only 2 per cent of the total. Improved efficiency will, however, become of importance when a large-scale chemical industry is set up using the by-products of the sugar industry as an input.

Bagasse represents almost 90 per cent of the total consumption of fuels in the sugar industry generating stations. In 1959, 12 million metric tons of bagasse were used for fuel.

As an indication of the possibilities of improving the efficiency of bagasse driven generating plants, it should be noted that some 20 per cent of the installed capacity in the sugar mills is accounted for by generating units that are over 40 years old.

As to the load factor, there would seem to be no possibility of any substantial increase in the near future such as to allow for a decline in the investment required to meet a given level of demand for power. In 1959, the load factors of the Eastern and Western systems of the Compañía Cubana de Electricidad were 0.61 and 0.53 respectively, which would seem a very satisfactory level considering the degree of economic development of Cuba. In the improvement of the load factor, a part was also played by the substantial reduction decreed in

electricity tariffs which undoubtedly led to increased use of household electric appliances at hours other than demand hours of peak.

For the purpose of overall projections of demand in the electricity sector and the consequent planning of the expansion of supply, the Sectoral Programming Department of the Central Planning Board adopted as a basis the regression equation of electricity production with respect to gross domestic product.

Using the figures corresponding to 1948-59, an elasticity was obtained of 1.75, but with an extremely low coefficient of correlation (0.69), and as a result far from satisfactory for the purposes pursued.

Excluding the sugar industry from the statistical analysis of the electricity sector, both as regards the independent and dependent variable of the regression equation, and taking into account the fact that the years 1958-59 may be considered abnormal, the adjusted curve for the period 1948-57 can be expressed by the following equation:

$$Y = 0.0109\ X^{1.773}$$

when X represents gross per capita domestic product (excluding the sugar sector) and Y the per capita production of electricity (also excluding the sugar sector).

The coefficient of correlation between the series so defined is 0.96 and elasticity 1.77. This is what was used as a basis for calculating overall projections; these showed a level of electricity production for 1965 of 6,150 million kWh (excluding the sugar sector).

The time required to bring about interconnexion between the public service electricity system of the Eastern and Western parts of the island will be determined by the date at which the steel mill, that is to be part of the Eastern System, comes into operation. The proposed date is 1965. In these circumstances, maximum demand in the interconnected system is likely in 1965 to reach a figure of 1 million kW.

Forecasts for self-supply production industry (excluding sugar) and mining are for 850 million kWh by 1965; for a degree of utilization of 5,000 hours a year (or somewhat higher than the 1959 level of 4,500 hours), this would require an installed capacity of 170 MW.

/What is

What is likely to be the future of electricity capacity in the sugar industry? This is hard to forecast, since it will basically depend on the volume of sugar production and also on improvements in the present low degree of utilization of generating equipment, although, as has already been stated, there are limitations in this respect resulting from the structure of the productive process in the sugar industry.

In general terms, it can be stated that investment in electricity equipment in the sugar sector in the forthcoming years will be primarily intended for the replacement of obsolete units to improve the efficiency of bagasse combustion rather than to make a net increase in installed capacity.

As a result, on the basis of the foregoing assumption, the total generating capacity which would be required in Cuba to meet demand in 1965, would be of the order of 1.7 million kW, 70 per cent of which would be represented by the interconnected public service system of the Compañía Cubana de Electricidad and the remainder by industrial self-suppliers.

As has already been seen, the estimated expansion of electricity demand in sectors other than the sugar sector was based upon the assumption of an elasticity as between electricity consumption and gross product of the order of 1.77 resulting from the regression analysis of the series corresponding to the period 1948-57.

The hypothesis for the increase in domestic gross product (excluding the sugar sector) made by the Central Planning Board was an annual cumulative rate of 10.5 per cent per capita. Bearing in mind that the sugar sector will grow at a considerably slower rate and in view of that sector's importance in the Cuban economy, such a hypothesis represents a somewhat smaller increase - probably of the order of 9 per cent annualy - in per capita income, but it must be realized that even this figure represents an ambitious target.

On the other hand, the hypothesis adopted for elasticity is relatively conservative, since it is confined to extrapolating for the six year period 1959-65 the rate of electrification (expressed as an annual percentage increase

/in electricity

in electricity consumption per unit of gross product, excluding sugar) for the period 1948-59. It is to be supposed, however, that if progress is made with the industrialization programmes, including the establishment of heavy industry, as a basis for the development process, a structural modification will be required in the economy which will markedly intensify the above rate of electrification.

The aforementioned trends are to a certain extent compensatory. This means that an inadequate increase in gross product in relation to the target fixed may be compensated, for the purposes of its repercussions on electricity demand, by a rate of electrification in the economic system exceeding the forecasts in the plan.

6. Chile

The basic characteristics of Chile from the electricity point of view are: high electricity consumption in relation to gross product, the large proportion of self-supply in the total of installed capacity (about half), and the great and growing predominance of hydroelectric power in the public service sector. It should also be added that the large-scale copper mining industry represents three-fifths of the installed capacity of self-suppliers.

In such conditions, any projection of electricity demand must be divided into two parts: the first for the copper industry; and the second for the rest of the economic system whose rate of growth, in its turn, will depend to a large extent on copper production, since copper exports account for more than half Chile's capacity to import.

Consumption of electric power in the copper sector will depend basically on the following factors: (a) copper demand on the world market; (b) Chile's share of the world copper market;[7] and (c) specific consumption of electric power in the copper industry expressed in kWh per physical unit of product.

The Chilean economic development programme prepared by the Corporación de Fomento de la Producción (CORFO) provides for an increase in copper exports from 466,000 tons in 1957 to 760,000 tons in 1968, or an annual rate

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7/ This is at present about 40 per cent.

/of increase

of increase of 4.7 per cent. This is based on a projection made by the Copper Department, based on figures and direct information supplied by the producing concerns. The level of exports in 1960, however, failed to reach half a million tons, or was more than 10 per cent below the amount projected.

In recent years, consumption of electric power by the copper mining industry has represented approximately one-third of the country's total consumption. In 1957, the copper industry's electricity consumption was 1,360 million kWh for an output of 451,000 tons of copper, or specific consumption of some 3 kWh per kilogramme of copper.

This average specific consumption in the copper sector will naturally vary not only in relation to technical developments in manufacturing but also to the percentage of copper blister in total output. In the absence of any satisfactory basis for forecasting future trends in either of these variables, we have in our projections used the same figure for specific consumption as that given above.

For the rest of self-suppliers, it would seem reasonable to take a higher rate of increase in consumption (not necessarily in their generating capacity, since hydroelectric generation by ENDESA will tend to absorb a growing proportion of total consumption in the Interconnected System) for the industries concerned include the steel, paper, chemical, etc. industries where there is reason to assume a relatively high rate of development with a view to establishing a dynamic basis for the industrialization process.

As may be seen in the relevant table, total power consumption, which in 1959 was 4,200 million kWh, should increase to about 7,600 million kWh in 1970 on a hypothesis of an average growth in the economy in keeping with a two per cent annual increase in <u>per capita</u> product.

We shall now turn to the expansion programme for public service installed capacity. Firstly, Chile is a typical case of a phenomenon that is very common in Latin America, namely, restriction of electricity demand owing to scarcity and resulting limitation of supply. As ENDESA observes in the introduction to Plan de Electrificación 1959-72, the result has been that while consumption in some areas of the country has

/doubled in

doubled in periods of three to six years in other areas (those where restrictions and rationing have been applied) twenty-three years have been necessary for consumption to double.

The Chilean electricity system has two separate and clearly distinguishable parts: (1) the first geographic zone, in the north of the country, which includes a quarter of total installed capacity and where generation is exclusively thermal and is in the hands of self-suppliers, mainly the copper industry; (2) the Interconnected System (we use this name although a few sections must still be filled in before interconnexion becomes complete), which covers the entire area between Copiapó and Puerto Montt (1,630 km) and includes the second, third, fourth and fifth geographical zones. The installed capacity in this area is predominantly hydroelectric and represents three-quarters of the total, since the remaining two geographical zones (the sixth and the seventh) account for only 1 per cent of total installed capacity.

At the end of 1959, installed capacity in the area covered by the Interconnected System included: (a) 375 MW, ENDESA, all hydroelectric capacity; (b) 166 MW, Compañía Chilena de Electricidad (subsidiary of the American and Foreign Power Inc.) of which 88 MW were hydraulic; (c) some 200 MW in the hands of self-suppliers, including the 55 MW of the hydroelectric generating stations of Coya and Pangal (Braden Copper) which are not incorporated into the Interconnected System as they operate on a different frequency. With this exception, the participation of hydroelectric capacity in the Interconnected System amounts to two-thirds; the equivalent percentage for generation is even higher, owing to the higher degree of utilization of hydraulic capacity.

As already stated, there are large-scale self-suppliers connected with the Interconnected System. The Interconnected System seeks to make the most efficient use of the complementarity of river basins and the accumulation capacity of the lakes of the area.

The System's present deficit in installed capacity in relation to potential demand (including reserve requirements) in the area which it serves, is estimated at some 200 MW, and in accordance with ENDESA plans this will not be covered until 1966.

/ENDESA's plans

ENDESA's plans provide for the addition of some 400 MW of capacity towards the end of 1964 and an additional 650 MW during the subsequent six years. Under this plan, real demand in the System will continue to be below potential demand until 1966 owing to inadequacy of supply.

In preparing demand forecasts, an annual growth rate of 7 per cent was adopted for the period of recovery from the present deficit (1959-66) and a rate of 7.5 per cent was adopted for the period 1966-72. As ENDESA points out, these are minimum figures and may well be exceeded if the country's development proceeds satisfactorily.

It is also estimated that in the forthcoming decade the Compañía Chilena de Electricidad will install at least 200 MW of thermal capacity, and this means that if the company simultaneously replaces its obsolete facilities, it will have available at the end of 1970 some 366 MW, while ENDESA would have 1.4 million kW.

At the same time, and due consideration being given to the hypothesis already referred to regarding the position of the copper industry it can be estimated that the copper sector should, at the end of the decade, have available not less than half a million kW. As to other self-suppliers, situated for the most part in the area covered by the Interconnected System, there is reason to suppose that they will make greater use of the hydroelectric capacity of ENDESA and as a result will not need to increase their own generating capacity to the same extent as their manufacturing capacity. Accordingly, we have estimated that self-suppliers would need an installed capacity of 300 MW by 1970.

The total would then be approximately 2.6 million kW. With a degree of utilization equal to 1959, this capacity would be sufficient to generate more than 10,000 million kWh, and this would seem to be adequate if we compare this figure with our estimates of the difference in production from one year to the next up to 1970.

At the end of the decade, the percentage share represented by self-suppliers in total installed capacity will have declined by from 50 to 34 per cent. Even so, this proportion will continue to be one of the highest in Latin America.

/The Overall

The Overall Economic Development Programme for the next decade prepared by the Corporación de Fomento de la Producción lays down as a target an annual rate of increase for product of 5.5 per cent.

The coefficient of investment, for its part, has in general been low, fluctuating in the neighbourhood of 10 per cent. The CORFO programme provides for a domestic savings coefficient of 10.4 per cent in the first year (it is supposed that there will be foreign capital assistance), with the figure increasing gradually to 18.8 per cent in the last year of the plan (the net external aid of the early years being paid back in the later years of the plan). The programme also provides for an annual rate of increase in manufacturing productivity of 3.6 per cent and a total increase in the index of production in the manufacturing sector of 7.25 per cent.

In Chile as in many other Latin American countries, there is a wide margin for increases in industrial production without appreciable investment in the industrial sector or supplementary investment in the electricity sector being required.

This is due to the fact that industry has a low degree of utilization of its productive resources. According to CORFO estimates, the degree of utilization in 1957 was only 48 per cent of capacity which was in principle installed, and this means that manufacturing output could be doubled without additional investment in equipment and, a point which is of particular importance from our point of view, without any substantial increase in maximum demand for capacity corresponding to the load diagram in the manufacturing sector connected to public service systems. This would be equivalent to a very considerable increase in the load factor of industrial demand and would naturally have repercussions on the load factor of the overall diagram. The low degree of utilization of manufacturing capacity is one of the factors which accounts for the low load factor of the electricity systems in many of the countries of Latin America.

7. Mexico

Until 1960, the Mexican electricity system was in the hands partly of State organizations, in particular the Comisión Federal de Electricidad (CFE), and partly of various private concerns, the most important of these being the Compañía Mexicana de Luz y Fuerza Motriz - CMLF, and the system belonging to a subsidiary of the American and Foreign Power Company Inc. In the middle of 1960, the CFE had a generating capacity of 1.2 million kW or approximately half the total public service installed capacity. The CMLF, the main privately-owned concern, had some 600 MW and the other privately-owned concern 340 MW, while self-suppliers accounted for 550 MW.

The share of total capacity that was hydroelectric was 44 per cent and thermal power was as much again, while the remainder was accounted for by internal combustion units.

During 1960, the Mexican Government acquired control of the two main privately owned electricity undertakings; in the case of the subsidiaries of the American and Foreign Power Company Inc. the Government proceeded by direct acquisition of the Company's assests and in the case of the CMLF by purchasing sufficient shares to ensure control of the company.

The most important part of the Mexican electricity map is the interconnected system of the Federal District which will henceforward be referred to as the Central System. It includes essentially the facilities of the CMLF (now under State control) interconnected with the Miguel Alemán hydroelectric system of the CFE.

The Central System is at present served by three thermal plants and 21 hydroelectric plants - including the five of the Miguel Alemán system -, with a total capacity of 930 MW, 352 MW of which 352 are in the hands of the CFE. This system represents one third of the country's total installed capacity.

At the end of 1960, the fourth thermal unit of the Lechería plant was incorporated into the Central System and at the end of 1961 the hydroelectric plant of Mezatepec on the river Apulco (156 MW installed capacity) will also be incorporated into the Central System. The System's generating capacity will thus be increased to 1,176 MW.

/Within the

Within the Central System, power is carried by high tension lines operating at 220, 150 and 85 kV, although all current is delivered to the Federal District at 85 kV as the primary distribution voltage.

From 1951 to 1958, the Central System registered average annual increases of 9 per cent both in maximum demand and in power consumed; but if the last four years of the period are considered in isolation, the average rate rises to 10 per cent. The latter figure is the one that has been adopted by the CFE for the purposes of its policy of expanding the System's installed capacity. Maximum demand of 1.3 million kW and annual generation of the order of 6,500 million kWh are anticipated for 1964.

The main additions to the Central System provided for in the coming years include: (a) by the CMLF, two new thermal plants of 125 MW each (extension of Lechería and possible construction of another plant), the first of these to enter into service in 1962 and the second in 1963; (b) by the CFE, one hydroelectric plant at Atexcaco in the Apulco area with three units of 50 MW each.

Only with these two additions will the Central System reach in 1964, the figure of 1.6 million kW, three fifths of the power being of hydraulic origin. This capacity will be sufficient to cover maximum demand forecast for 1964 and leave an adequate margin of reserve, on the hypothesis that new consumption centres are not added to the Central System.

It should naturally be remembered that not only the load demand but also the demand for power is a limiting factor, particularly in systems where a relatively large percentage of power is generated hydraulically. This is true of the case considered here, which has in addition, a very irregular river régime. With a degree of utilization of 2,400 hours annually estimated for the hydroelectric plants in years of drought[8/] and 7,400 hours for thermal plants (approximately 0.85 as the plant factor), available capacity in 1964 would provide a total of 6,800 million kWh, or 5 per cent more than the demand for power forecast for that year by the System's present consumers on the assumption of an annual rate of growth of 10 per cent.

8/ See A. Fernández del Busto, "El sistema interconectado de la Zona del Distrito Federal", Revista Técnica JEM, September 1959.

/There would

There would not accordingly seem to be sufficient margin to add new consumption centres to the System unless the expansion plans for generating capacity are simultaneously broadened, and this is true even though the hypothesis adopted is somewhat conservative, in view of the pattern of the capacity of the hydraulic part of the System.

The present plans of the CFE provide for an increase in the System's capacity larger than that needed to satisfy present consumers. The CFE plans provide that, in the five-year period 1960-64, installation in the whole country will amount to 3.3 million kW, nearly a million of which would be additions to the Central System, 750 MW to Puebla and Veracruz and 400 MW each to Falcón, Monterrey and the north eastern area of the country. It may be that the installation of the total amount of this capacity will not be ready by 1964 and as a result a part may have to be completed in the subsequent five-year period.

The distribution of generating plants within the Central System is asymmetrical. There is a large concentration of hydraulic capacity to the south of the ring while there is a preponderance of thermal capacity to the north. This means that the problem of transporting large blocks of power through the System has to be faced to meet current hydrological conditions. This has given rise to the idea of building an outer double circuit ring of 220 kV during the next decade.

It should be noted that the CFE expansion plan provides for rather more than half of new capacity being hydraulic.

If the new thermal plant of 250 MW of the CMLF and the extensions of other concerns including those which were formerly subsidiaries of the American and Foreign Power Company Inc. are added to the 3.3 million kW which the CFE proposes to install, it can be estimated that, provided all these plans are carried out normally, installed electricity capacity at the end of 1965 will be between 5.5 and 6 million kW. In those circumstances, Mexico will take Argentina's place as second only to Brazil as regards installed capacity. Brazil is forecast to have an installed capacity of 8 million kW in 1965.

/One of

One of the problems of electricity development in Mexico is the large number of small and widely dispersed hamlets where a large proportion of the population resides.9/

The 1960 census shows that only 47 per cent of the population lives in localities of over 2,500 inhabitants although relative population consolidation has occurred recently. The above percentage was 42.3 in 1950 and 35.0 in 1940.

The obstacles which such wide dispersal of the consumer market puts in the way of satisfactory development of electricity supply are quite obvious. The wide scattering of the population combined with low per capita income levels means a level of electricity consumption per square kilometre that is singularly low, and this in its turn leads to a low level of capacity required in terms of kW per kilometre of radius. The low figures of this latter coefficient mean that installed capacity has also to be scattered in numerous small plants with the consequent increase in installation and operation costs, or else power must be transmitted relatively uneconomically in small amounts over great distances. For a number of years a policy has, however, been pursued in Mexico of gradually extending electrification to areas bordering on the large systems and transmission lines; this policy has met with good results. It is proposed to pursue it in the future.

8. Peru

The most complete study of the overall electricity situation in Peru together with a programme for future expansion was prepared in 1956 by a mission of Electricité de France contracted for that purpose by the Peruvian Government.

At the beginning of 1956, when the study was initiated, the Peruvian electricity system consisted of a large number of isolated networks whose capacity was usually very small. There were two exceptions: the network of the concessionnaire supplying Lima and the network of the Compañía Minera

9/ See Antonio González Rivera, Development of electricity systems in Mexico, by regions (ST/ECLA/CONF.7/L.2.24).

Cerro de Pasco; these two represent 47 per cent and 16 per cent respectively of total guaranteed capacity in the country. Total installed capacity was estimated in 1956 at 430 MW, 44 per cent of which corresponded to the public service. Of that total, hydraulic capacity represented 56 per cent, thermal steam capacity 17 per cent and diesel capacity 27 per cent.

The high percentage of diesel generation gives an indication of the low degree of integration and the small size of the majority of electricity generating stations in Peru.

A large part of hydraulic capacity is in the hands of the Lima concessionnaire whose extension policy has been directed essentially towards the electrification of the Rimac and Santa Eulalia river basins; at the end of 1955, the concesionnaire had an installed capacity of 136 MW (112 hydraulic, 10 gas turbine and 14 steam turbine) to meet a maximum demand of 114 MW. In addition, Cerro de Pasco and the Corporación del Santa have considerable hydraulic capacity.

In what way did this situation change between 1955 and 1959? At the end of 1959, total installed capacity had increased to 718 MW, 320 MW of which belonged to the public service (with continued predominance of hydraulic capacity at 73 per cent of the total), the rest being in the hands of self-suppliers. Out of the total of 718 MW installed, hydraulic capacity represents 57 per cent and this means that its percentage share is much smaller among self-suppliers than in the public service. Diesel generation units continue to occupy an important place (almost a quarter of the country's total capacity).

The degree of utilization for its part does not differ very much as between the public service and privately-owned concerns the figure in both cases being slightly above 3,000 hours annually.

Attention should be drawn to the marked fall in the percentage share of hydroelectric generation in the total. It fell from 82.1 per cent in 1949 to 74 per cent in 1955 and 61.4 per cent in 1959.

The preponderance of self-supply systems in Peru is due mainly to the existence of a highly developed mining industry and large-scale agricultural undertakings distributed geographically in widely-separated areas far removed from large population centres. Examples of this are Cerro de Pasco and Toquepala.

/It is

It is interesting to study how the Peruvian National Electrification Plan has developed since it was drafted. The Plan, which was drawn up when the country's installed capacity was estimated at some 430 MW, provided for the installation in the subsequent twenty years (1955-75) of 29 new power stations with an additional installed capacity of 2,000 MW. Of this amount the following was installed between 1955 and 1960:

(a) The fourth group of the Callahuanca power station, with 31 MW;

(b) The first stage of the Puacartambo power station with 65 MW;

(c) The first stage of the Cañón del Pato power station, with 52 MW and

(d) The Huampani power station with 30 MW.

Of the remaining public service power stations included in the electrification plan, particular attention should be drawn to the Huinco plant in the upper valley of the Santa Eulalia (tributary of the Rimac), with 120 MW in its first stage, later to be extended to 180 and 240 MW in successive stages, and more especially to the Mantaro project for which the forecast installed capacity is one million kW. The utilization of the Mantaro[10/] which will, in accordance with the Plan, supply the Lima area in the final stages of execution, is needed in view of the fact that the Rimac basin will prove too small to meet demand in that area.

We have already referred to the large amount of diesel generation of electricity in Peru. There are more than 600 internal combustion power stations

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10/ Some years ago, a proposal was made for the construction of a tunnel, 43 kilometres long, through the central area of the Andes deviating the course of the river Mantaro to the Rimac valley. Such a diversion (which would provide some 30 cubic metres of water per second) would increase the hydroelectric potential of the Rimac which flows through Lima and Callao into the Pacific and would also provide larger amounts of water for irrigation in the Lima area.

At the same time, however, such a deviation, whether partial or total would reduce the possibility of establishing a large hydroelectric plant on the Mantaro below Huancayo.

The problem therefore is of the greatest interest and value, both technically and economically. In a recent more detailed regional study a different project was proposed, the argument being put forward that the original project would go against the development interests of an already densely populated area while the availability of electric power at very low cost in the eastern area of the Andes would make it possible to set up a dynamic regional development centre in an important area of the country.

There is also the possibility that if the hydroelectric sources o the Rimac and other rivers close to Lima (such as the deviation of the Marcarpomacocha into the Santa Eulalia) eventually become exhausted, a transmission line could be established to supply the Lima area.

/In the

in the country representing one quarter of total installed capacity. This can be explained both by the fact that diesel units allow of greater fractioning of capacity than steam plants and also by their smaller consumption of water.

The plan drawn up by Electricité de France provided for the establishment of 22 diesel plants with a total capacity of 43 MW and 7 steam stations with a total capacity of 273 MW, including 75 MW for Callao, 110 MW for Ilo (the Toquepala mine) and 55 MW for the sugar mills in the north. Objections were raised to these projects by some Peruvian experts who doubted whether it was advisable for a study group to plan the future expansion of privately-owned industries of such a highly individual type as mining and sugar-refining.

As regards the degree to which aggregate electricity generation is integrated, it should be pointed out that the principal production centres in Peru, i.e. those of the Lima concessionaire, of Cerro de Pasco, of the Corporación del Santa and of the sugar industry in the north, operate completely independently of one another.

At the present time a 132 kV line is being set up to connect the Ilo thermal plant (44 MW) with the Toquepala mine 150 kilometres away.

The Electricité de France plan recommends that the Cerro de Pasco and Lima systems be interconnected by a transmission line with a voltage of 220 kV; this is, however, a highly debatable question.

The implementation of the electricity programme seems to be progressing satisfactorily since installed capacity expanded at the rate of 13 per cent annually from 1954 to 1959; this rate compares favourably with that of 10.6 per cent recorded in the preceding decade and of 6.1 per cent from 1940 to 1959.

Furthermore, at the end of 1959, generating plants with a total capacity of 540 MW were under construction; this figure is equal to 75 per cent of capacity already installed at the time (718 MW). One indication of the dynamic way in which electricity installations in general are expanding is the fact that the above-mentioned figure is exceeded only by Brazil which, on the same date, had some 4 million kW under construction, i.e. more than 100 per cent of its existing capacity.

/The rate

The rate at which electric power demand has been increasing is slightly less than that projected by Electricité de France; in 1954-59 it was 10.2 per cent as against the projected figure of 13.3 per cent for 1956-63. The high rate assumed was partly an expression of the recommendation to make up for the lag in growth; from 1963 onwards the annual growth rate was projected as remaining stationary at 9.3 per cent.

Generally speaking, it may be concluded that, if the 540 MW that were under construction at the end of 1959 are added to the 718 MW that already existed at that time, Peru would have an installed capacity of over 1.2 million kW before 1965, i.e. by then it would have gone halfway along the path indicated by Electricité de France and in ten years would have tripled its installed capacity. If work plans continue to be implemented at the same tempo the programme's targets will be duly attained.

/9. Uruguay

9. Uruguay

It is particularly important to analyse the situation of the electricity sector in Uruguay because of its connexion with the Salto Grande plant, which will be discussed in the section on Argentina. References to it at this juncture will therefore be brief.

In 1959 generation was 1,200 million kWh, 93 per cent of which is generated and consumed by the interconnected Montevideo-Rio Negro system which supplies the centre, south, south-west and part of the east and north-east of Uruguay. The entry into production of the Rincón de Baygorria hydro plant in 1960 brings installed capacity up to 406 MW, of which 170 MW are thermal and are concentrated in the Batlle power station at Montevideo and the remaining 236 MW are hydraulic and are to be found in the two plants on the Río Negro. Maximum demand in the winter of 1961 is expected to be about 300 MW.

With an annual rate of increase of slightly more than 9 per cent, maximum demand in the system during the winter of 1971 is projected as being about 750 MW; this which would require an installed capacity of some 900 MW.

The following works are under consideration and preliminary projects already exist for some of them:

(a) a peaking plant (gas turbine) of 40 MW;

(b) expansion of 60 MW in the Batlle plant;

(c) first and second units of 125 MW each in the Punta del Tigre thermal plant at Montevideo;

(d) the Paso del Puerto hydro plant with 160 MW;

(e) the Salto Grande hydro plant with 700 MW for Uruguay.

The first four projects will undoubtedly have to be carried out and put into operation during the present decade, since all the additional megawatts they represent are needed if the system is to have the requisite capacity by 1970. Moreover, for the reasons already given in the case of Argentina, at best the Salto Grande plant will not begin to operate before 1969. The question of this plant is therefore considered in relation to the alternative solutions of two other thermal units of 125 MW at Montevideo or a new hydroelectric plant on the Río Negro downstream from the three others that would have been built by then.

/The construction

The construction of the Salto Grande hydroelectric plant gives rise to problems for both Argentina and Uruguay with respect to the question of ownership. These problems call for careful study, and, in our opinion, have not given their due realism up to now since, on one ground or another, any attempt to examine and solve them has been postponed.

For example, in the case of Uruguay, it was assumed that this country would defray half the cost of the works in exchange for approximately 700 MW from the moment the plant entered into production. Given that the successive increments in peak demand in the system would amount to about 70 MW by the end of the decade, it would take nearly ten years for the Uruguayan electricity network to absorb the extra power available at Salto Grande. Even though both fuel and labour could be saved in the Montevideo thermal units, there is no doubt that such a prolonged period of absorption would unduly raise the cost of the energy consumed owing to the accumulation of interest during construction when capacity was necessarily lying idle.

The installation of mechanal and electrical equipment could of course be deliberately postponed, but in any case there the civil engineering works, which form the major part of the total investment cost, would represent a heavy additional charge.

One solution to the problem would be the sale of power to Argentina. At the end of the decade the stepped increments in maximum demand in the system that supplies Greater Buenos Aires would be about 200 MW; this means that in slightly over three years Argentina could use the whole of the capacity corresponding to it in Salto Grande and would be in a position to buy electric power from Uruguay. It could even do so earlier if utilization of the thermal plants already established at Buenos Aires were reduced.

It should be noted that Uruguay and Chile head the Latin American countries as regards the degree to which their electricity systems are integrated. On the total energy sold by the State public service monopoly, 95 per cent went to consumer centres served by the Montevideo-Río Negro system. Some independent units of small capacity worked by internal combustion engines are still to be found in the north and north-east, but they will gradually disappear in the course of the next few years as these parts of the country are incorporated into the national electricity network.

10. Venezuela

At the end of 1959, installed capacity in Venezuela was 1.3 million kW, and the energy generated was 4,300 million kWh of which 63 per cent corresponded to the public service.

This capacity may be broken down into the following big groups: (a) 212 MW for the CADAFE networks; (b) 340 MW for Electricidad de Caracas; (c) 100 MW for the first units of Macagua I which is, in its turn, the first hydroelectric plant to be built on the River Caroní; (d) 350 MW for the petroleum companies and 84 MW more for other self-suppliers; (e) 176 MW for other public electricity companies, including 100 MW for Electricidad de Maracaibo.

These figures show that utilization of capacity in the public sector was relatively low (some 3,200 hours annually), which seems to indicate that there was an excess of means of production at that time.

More than half the installed capacity of the public services has a generating frequency of 50 cycles, i.e. 140 MW of the CADAFE networks and the total installations of Electricidad de Caracas. The remaining capacity is designed for generation at 60 cycles.

This duality creates a serious problem for the future interconnexion of Venezuela's electricity systems, which will be discussed later when their respective expansion programmes are under review.

Of installed capacity at the end of 1959 only 10 per cent was hydroelectric. Most of this percentage consisted of the 100 MW already installed at that time in Macagua I. By the end of 1961, this figure will be completed by the addition of a further 200 MW in Macagua and 365 thermal MW, a third of which will correspond to Electricidad de Caracas, 162 MW to the CADAFE networks and 84 MW to the Maracaibo network.

Installed capacity in Venezuela would thus be at about 1.9 million kW, by the end of 1961, of which a sixth would be hydraulic. This proportion would diminish towards the middle of the next decade and thereafter expand again as a result of the emphasis which, as will be explained later, will be laid on long-term hydroelectric projects. This emphasis is logical in the case of Venezuela, since its estimated capacity of some 16 million kW (approximately 10 per cent of Latin America's entire capacity) makes it one of the best-endowed countries in the region as regards hydroelectric resources. Of these 16 million kW, 14 million correspond to the Lower Caroní and the remainder to other zones, particularly in the vicinity of the Andes.

/Utilization of

Utilization of the Caroní will thus be the backbone of electricity development in Venezuela during the next few years. The Coroní Commission has concentrated on making studies of Macagua II and, in particular, of Guri, where the regulating dam for the whole lower Coroní is to be built to interbalance the great irregularity of the river's flow.

The cost of harnessing the Caroní for hydroelectric production is very moderate, and, above all, the big consumer centres are fairly near. In fact, it is estimated that during the early stages of utilization, provided that the best sites are chosen for regulating flow and installing the machinery, nearly 3 million kW could be obtained at a cost of some 200 dollars per kW, including transmission within a radius of 100 kilometres. This figure compares favourable with the unit costs of installation in thermal plants, which were 175 dollars per kW in 1950-60, even though the cost of the relevant transmission lines will have to be added once interconnexion has been made with Caracas.

The harnessing of the Caroní for hydroelectric production involves the transport of the electric energy generated to the big consumer centres, and raises the problem of duality in generating frequency. It will therefore be necessary to change the frequency of the Caracas system, and this will lead to costly modifications in the generating plants and in consumer facilities of all kinds. Moreover, a further problem would arise in respect to the price at which the hydroelectric plants in question should sell blocks of energy to private companies that put up the capital (Electricidad de Caracas and another company which confines itself to distributing and is a subsidiary of the American Foreign Power Company Inc.), and the relationship between that price and the retail sales price.

Hydroelectric energy from the Caroní is already needed in the consumer centres since the industrial complex set up in the area will not be able to use all the energy that can be generated by Macagua I for several years to come. The first step has been taken by setting up a 230 kW line some 500 km in length, between Macagua, Puerto La Cruz and Santa Teresa, which will carry energy from the Caroní to the centre of Venezuela. This line will subsequently be extended to Puerto Cabello, thereby supplementing the capacity of the thermal plant already installed there.

/The programme

The programme recently drawn up by a mission from Electricité de France provides for the subsequent establishment of a system which would stretch from the Andes and Maracaibo in the west to the eastern zone and the Guayana Shield in the south-east. Between 1965 and 1975 this system would be strengthened to enable it to cope with the increasingly large transfers of energy that would be needed in the Andean area and more particularly in the vicinity of the Caroní. With the interconnexion of the thermal plants in the intermediate zone with the hydro plants at either extreme, the network would become part of an integrated production system and enable due advantage to be taken of the varied nature of the load diagrams in the consumer centres thus linked up.

The final form of the CADAFE interconnexion network would thus be a big arc, some 1,200 km long, which would stretch from Guri in the east to Uribante in the west. This network will operate in an integrated way as soon as the first Guri groups enter into production in 1967.

The decision as to whether Caracas should or should not be linked up with the CADAFE system may be deferred until the Guri groups enter into operation. Apart from the benefits that would derive from harnessing the energy potential of the Caroní for consumption in Caracas, a powerful incentive to interconnexion is the fact that the CADAFE systems capacity could thus be supplemented by the thermal capacity installed at Caracas, which would be about 800 MW by 1967.

There is also a possibility, which is mentioned in the study by Electricité de France, that even after the Caracas system has been interconnected with the CADAFE network it might continue to generate at 50 cycles and to transmit energy by means of a continuous current. In this case, it might be worth while to defer the incorporation of Caracas into the nation electricity network, since this form of transmission is economical for very large power blocks only.

At the end of 1959 the 50-cycle networks in the CADAFE system were suffering from a shortage of production equipment, while there was a surplus of energy at 60 cycles. Provision was made to standardize the frequency of these networks by the end of 1962.

/The following

The following paragraphs contain an analysis of the electricity development programme which forms part of the Venezuelan Government's Four-Year Plan (mid-1960 to mid-1964). The compatibility of this programme with the projections of demand will be discussed at the conclusion of the analysis.

In general, the programme contemplates the net addition of a million kW to the public service sector, two fifths of which would correspond to private companies and the remainder to CADAFE and the Caroní Commission. The extra capacity for the private companies will be entirely thermal, the large proportion of 240 MW being earmarked for Electricidad de Caracas. Of the 600 public MW, half will be for Macagua I and the other half for the CADAFE thermal installations.

If this programme is implemented, the public service capacity would be about 1,650 MW in 1964, divided into equal parts between private and State enterprises. Within the private sector, Electricidad de Caracas would have three quarters of the available capacity.

The governmental programme also provides for the beginning of work on the Guri plant. The building of the dam is expected to start during the 1962-63 fiscal year. Further reference will be made to this point when the expansion of capacity during the second half of the next decade is being analysed, but, in view of the fact that the governmental programme takes 1964 as its limit, the projections of demand for that year will be examined earlier so that energy requirements can be compared with the projected additions to generating capacity.

In the Four-Year Plan, the projection of electricity demand is mainly based on one of the so-called second category, or indirect, methods, by which, on the one hand, industrial electricity consumption is related to the trend of manufacturing production and on the other, domestic and commercial consumption is related to the income level of the population. The problem was therefore split into two parts: in the first, the product-elasticity of industrial electricity demand was calculated, and in the second, a linear regression was made between per capita domestic electricity consumption and per capita national income. After an elasticity coefficient of 1.65 had been obtained for industrial demand, the expansion

/of demand

of demand was calculated in accordance with the projected growth of the industrial product during the period, which is 12 per cent annually. The resulting figure obtained for industrial electricity consumption in 1964 was 1,700 million kWh.

The linear regression between per capita domestic and commercial consumption and per capita income is expressed by the following equation, which is based, as in the previous case, on the figures for the decade ending in 1958:

$$e = 0.1257\ y = 176.53$$

If national per capita income (estimated for 1964 at 3,400 bolivares) is applied to this equation, the figure obtained for per capita consumption is about 250 kWh which, multiplied by the population (estimated to be 7.8 million on 30 June 1964), gives a total demand for the sector of 1,950 million kWh.

To these figures should be added demand in industries that have a high electricity consumption per unit of product, such as the Matanzas steel mill, the Petro química de Marón and the projected aluminium plant. It is estimated that by 1964 their joint consumption will be 1,850 kWh, which exceeds the figure calculated for the rest of the manufacturing sector existing in 1958.

Total public-service demand in 1964 would thus be 5,500 million kWh. If losses under the head of generation, transmission, distribution, and internal consumption in the plants themselves, persist at the same rate as in the last two decades (20 per cent), some 7,000 million kWh would have to be generated in 1964.

This projected increase in generation by the public utility - from 2,700 million in 1959 to 7,000 in 1964 - implies an annual growth rate of about 20 per cent (11 per cent if consumption by the three above-mentioned industries is excluded), i.e. one similar to that recorded for the public service in the fifteen years following the war.[11/] It is apparent from this that the rate of increase of electricity production is to be maintained, even though the target contemplated in the Plan for the expansion of the gross product (7 per cent yearly) is 2 per cent lower than that attained

11/ If generation by self-suppliers is included, the average rate of growth would be 16 per cent.

/in the

in the foregoing period which was mainly attributable to the highly favourable conditions of the international petroleum market.

The generation of 7,000 million kWh, added to the 1,650 MW available in 1964, would require a utilization of 4,200 hours, i.e. considerably more than in 1959 when, as already stated, it was 3,200 hours. It is hoped reach this target primarily by devoting the major part of production in the Macagua hydro plant to continuous-process industries, thereby enabling the plant to operate with a high utilization factor in view of its favourable load diagram.

It should be noted that the projection in the Four-Year Plan, which assumes that demand would double in less than five years, is more optimistic than that made in the study by Electricité de France for the same period.

The Four-Year Plan naturally makes no reference to the situation of electric power supply and demand in the second half of the decade. The basic information therefore has to be obtained from the study by Electricité de France. This study examines two different hypotheses on the expansion of demand after 1965 - one postulating the duplication of per capita electricity production in ten years and the other assuming the duplication of total electricity production in the same length of time. The second hypothesis is based on an annual growth rate of 7.2 per cent and the first on a rate of 10.5 per cent (due consideration being given to the fact that the rate of population increase is about 3.2 per cent), which is close to the rate of 11 per cent recorded in the preceding quinquennium.

Both hypotheses exclude from their starting-point - consumption in 1965 - the requirements of Petro química de Morón and the Matanzas steel mill (which at that time would have a maximum demand of approximately 300 MW), since it was considered that the two plants would probably have reached their ceiling by then. This assumption is, however, open to doubt, since if the country develops at a satisfactory pace, these industries will embark upon a certain amount of equally energy-consuming expansion, after 1965.[12/] There is also a possibility that new industries with a high

12/ The possibility of such expansion, and the studies which are already being carried out in this respect, are specifically mentioned in the Four-Year Plan (Vol. I, pp. 112-116).

electricity consumption, such as aluminium manufacture, may be established.

The two principal decisions - which, in actual fact, may be condensed into one owing to their close interdependence - relating to the expansion of the electricity sector after 1965 concern the interconnexion of the Caracas system with the national network, and the rapidity with which the generating plants can be installed at Guri.

In the case of Electricidad de Caracas, it is believed that it would not be able to embark upon the costly transformation of its 50-cycle network for interconnexion purposes until CADAFE could supply it with energy none cheaply than if it had to generate its own. This would be possible only after the Guri hydroelectric plant on the Caroní had entered into operation as envisaged in 1966-67.

Hence, the projections in the Electricité de France study were formulated on the basis of two different hypotheses as to the structure of Venezuela's electricity system during 1970-75, one of which assumes that the Caracas network would operate in isolation and the other that it would be interconnected with Guri.

Electricité de France considers that if the Guri works are constructed quickly enough, the first group could enter into production at the end of 1967[13] with 162 MW, the second by mid-1969 and the third at the end of 1970. There would thus be a further capacity of 486 MW available, while the addition of 225 hydraulic MW is contemplated for the western zone in accordance with plans for the first stage of utilization of the River Uribante in the Andes.

If it is assumed that there will be a halt in the development of the industries that are heavy electricity consumers, the rate of expansion postulated in the Four-Year Plan for the rest of industrial and domestic demand would coincide with the more optimistic hypothesis put forward by Electricité de France, i.e. that per capita electricity production would double in ten years.[14]

If a generation of 7,000 million kW is assumed in 1964, according to the Four-Year Plan, this would mean a generation of some 13,000 million in 1970 which at the same degree of utilization of 4,200 hours, would need

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13/ This period is somewhat longer than that specified in the Four-Year Plan.

14/ The duplication of total production in the same length of time seems to be too conservative a hypothesis.

an installed capacity of 3.1 million kW.[15/]

It would therefore be necessary to double public service capacity between 1964 and 1970. It has already been observed that, according to the Electricité de France study, the three first Guri groups and the first stage of the harnessing of the Uribante would provide some 700 MW in 1970. It remains to decide on the distribution of the other 700 MW required. A certain amount should be provided by Electricidad de Caracas even after interconnexion with Guri, since such interconnexion would not take place until the end of the decade, and it is patent that demand in Caracas would require the addition of not less than 400 MW in 1968-69 to the 580 MW already contemplated for the middle of 1964.

In short, it may be estimated that Caracas would have a million thermal kW at the time of its interconnexion with Guri, provided that this does not take place before 1970. If it does, the units at Guri and in the western zone should enter into production earlier than is planned, and the thermal part of the CADAFE plan for expansion should be revised accordingly.

The decision would depend fundamentally on the price at which electric energy from the Caroní could be sold in Caracas. To judge by the preliminary calculations which have been made in the Four-Year Plan, the sales price of very large power blocks would be about 0.1 bolivar. The fixed and operating costs (including losses) of the Guri-Caracas transmission lines should be added to that figure and the result compared with the cost of thermal generation at Caracas.

It should be noted for the purpose of comparing the respective costs of hydraulic and thermal energy, that the Electricité de France report assumes that the thermal plants would be run on natural gas. The mission based its views in this respect on the terms of the contract signed on 29 January 1960 by CADAFE and the Venezuelan Petrochemical Institute (Instituto Venezolano de Petroquímica) for the provision of gas to the Mariposa, Cabrera and Puerto Cabello plants.

15/ This degree of utilization may decline, however, if the proportion of electrometallurgical and chemical consumption is reduced in relation to the total.

/The contract

The contract specified a price consisting of a fixed charge - capitalized and related to the requirements of the generating plant - which corresponds to an investment of 75 bolivares per installed kW, and a charge related to consumption and fixed at 0.2 bolivares per cubic metre. The first obviously corresponds to fixed costs, particularly those arising from the installation of a transport net work, and the second to direct costs, i.e. the cost of operating such a network plus the cost of gas at the wells. The figures are based on a cubic metre with a calorific power of 9,344 calories, with which some 3.5 kWh can be obtained in the generating plant.

On the assumption of a utilization of 4,000 hours, the fixed charge per kWh would be 0.19 bolivares and the variable of others 0.06, giving a total of 0.25 bolivares per kWh for fuel. If capital charges are added, the cost of the high-voltage kWh could not drop below 0.4 bolivares. This leaves a margin of 0.3 bolivares as the ceiling for the share corresponding to the transmission of the Caroní hydroelectric load.

The rate of increase in the self-supplying sector, and the petroleum industry in particular, will undoubtedly be much lower than in the public service. The Four-Year Plan assumes an annual growth rate of 4 per cent for petroleum production, but electricity capacity may increase more slowly owing to the possible existence of idle capacity in industry at the present time and to the margin of reserve in electricity equipment. If an annual rate of 4 per cent is decided upon, this would be equivalent to adding 50 per cent to capacity by the end of the decade. Self-suppliers would thus have some 700 MW at their disposal which, together with the 3,100 estimated for the public service, would give a total capacity of 3.8 million kW.

Annex

COMPARATIVE ECONOMIC ANALYSIS OF A CONVENTIONAL THERMAL PLANT AND A NUCLEAR PLANT

1. Parameters of the problem

In this case, the fundamental parameters are as follows:

(a) The installation capacity of the plant.

(b) The relation between investment costs per kW of energy in the conventional thermal plant and in the nuclear plant. This relation is, in its turn, an increasing function of total capacity, i.e. of the first parameter given, which indicates that - at the actual stage reached by the respective technologies - economies of scale are more substantial in nuclear plants.

(c) The relation between the price of the fuels used in the two types of plants, i.e. coal, fuel oil and natural gas in the conventional plant and uranium and its derivatives together with other fissionable materials in the nuclear plant.

The production cost of the minerals in question is only one of the factors on which this relation depends, the most important being transport costs. These form a high proportion of the total - ranging from more than half to about a quarter of the cost in generating - in the case of conventional fuels and a small proportion in the case of fissionable materials owing to their high energy content per unit of weight. It is evident, therefore, that any increase in the distances involved or in the unit cost of transport will tip the balance in favour of nuclear plants. It should also be observed that the cost of international transport, as may be seen from table 7, is a more erratic variable than the f.o.b. price of fuel. As regards Latin America at least, it is difficult to generalize about internal costs, which are conditioned by distance and the existence of large-scale means of transport.

/Table 7

Table 7

WORLD MARKET PRICES OF BASIC COMMODITIES

	Coal (Dollars per short ton, f.o.b. prices United States port)	Fuel oil (Dollars per barrel, f.o.b. prices Gulf ports)	Freight rates (Swedish index: 1953 = 100)
1950	8.11	2.98	169
1951	8.76	3.36	315
1952	8.82	3.36	260
1953	8.39	3.40	100
1954	8.12	3.50	96
1955	8.56	3.61	135
1956	9.61	3.71	244
1957	10.00	4.02	165
1958	9.71	3.56	79
1959	9.38	3.69	70
May 1960	9.01	3.36	63

/(d) The

(d) The plant factor, or degree of annual utilization of the generating plant. As with any investment that implies a decrease in current or direct inputs per unit of product, more intensive utilization would tend to favour the technology that has higher installation costs and lower operating costs, i.e. the nuclear plant in the case under consideration.

(e) The capital charge coefficient adopted, i.e. the sum of the rate of interest and the assumed amortization period. Generally speaking, this coefficient will be greater in countries that are less advanced economically, in view of the influence of a higher interest rate, even if the useful life of the fixed capital may be longer.[1/]

(f) The relation between yields for energy transformation - combustion and fission - and heat transmission in the respective thermal units, i.e. the conventional boiler and the nuclear reactor.

There are other variables which should also be taken into account in specific cases, such as operating and maintenance costs (fundamentally, labour), etc. In order to simplify the general presentation of the problem, significant differences between the two cases under consideration have not been considered, or rather it has been assumed that there are none. This assumption is fairly sound since the order of magnitude of the costs in question is 0.001 of a dollar cent per kWh; hence, any difference that existed would be about four figures after the decimal point. Moreover, there would be no difficulty in incorporating such differences into the general outline.

2. General solution

According to the simplified hypotheses adopted, the formulas for the respective annual costs per installed kW of the conventional plant and of the nuclear plant are:

1/ For a more detailed analysis of this important parameter, see Methodology for forecasting electric power demand (ST/ECLA/CONF.7/L.1.10).

$$C = a.I + f.y.p.$$

$$C' = a.I' + f.y'.p'$$

the terms being as follows:

a = annual capital charge coefficient

I = unit cost of investment in the conventional plant

I' = unit cost of investment in the nuclear plant

f = load or annual utilization factor (in thousands of hours yearly)

y = thermal yield in the conventional plant (in thousands of calories per kWh)

y' = thermal yield in the nuclear plant

p = price of conventional fuel (in dollars per thousand calories)

p' = price of nuclear fuel

It should be noted that the capital charge coefficient is the same for the two plants. In some countries, particularly the United States, it has long been debated whether shorter amortization periods should not be adopted for nuclear plants since the progress of nuclear technology may make such plants obsolete more quickly. This argument does not appear to be very valid, since every advance in nuclear technology will also affect the relative economic merits of the conventional plants already built.

In order to obtain the break-even point p as a function of the other variables, both expressions should be equated and the resulting equation given in terms of p as follows:

$$p = \frac{a\ (I' - I)}{f.r} \Big/ \frac{p'\ .r'}{r}$$

Just as it was possible to estimate intuitively, this price limit - below which the conventional plant would be more economic - is an increasing function of: (a) the capital charge coefficient; (b) the cost of nuclear fuel and (c) the difference between the investment per kW in each plant (naturally assuming that $I \neq I'$), and decreases with the load factor.

/3. Order

3. Order of magnitude of the parameters

This aspect is dealt in another paper presented to the Seminar,[2] and any mention of it here will therefore be very brief.

With respect to investment costs, the conclusion reached by the IAEA in the above-mentioned study is that the large-scale nuclear plants to be constructed in the next five years will have a unit cost of installation about 1.5 times that of a conventional thermal plant of a similar size. They also point out that technical improvements could reduce this factor to 1.3 in the immediate future.[3]

There also seem to be better future prospects in nuclear technology as regards yields in energy transformation. In conventional thermal plants, the successive improvements in yield through the increase of work temperature and pressure are becoming less significant and more costly as yield nears the limits imposed by the laws of thermodynamics for the respective cycles.

In the nuclear field, however, important advances are still being made in the increase of combustion relations.

As regards the price of fuel, the reduction is more substantial in the case of fissionable material than of conventional fuels. Nonetheless it is difficult to forecast the trend of future events, since there is still no free market for fissionable material. In the IAEA study, it is stated that the price of natural uranium ($U_3 O_8$) in concentrates offered by the Agency has been reduced to 35 dollars per kg. More recent estimates by the United Kingdom Central Electricity Generating Board puts the price of natural uranium at 42 dollars per kg.[4] From these prices a credit of 17 dollars per kg must be deducted for the value of the plutonium obtained in the reactor, since - as in the case of the Calder Hall, Chapelcross and Marcoule plants - the reactors in question are of a dual type, i.e. they produce energy and plutonium.

2/ International Atomic Energy Agency (IAEA), Nuclear power costs and their trends with special reference to less developed countries (ST/ECIA/CONF.7/L.4.1).

3/ The unit cost for the Rowe nuclear plant of 150 MW (Massachusetts, United States) will be 340 dollars per kW, according to a statement made by Charles Weaver of the Westinghouse Electric Company to the Joint Committee on Atomic Energy, United States Congress, when he referred to the hydraulic pressure reactor made by the Yankee Atomic Electric Company (Electric World, 13 March 1961).

4/ In the first United Kingdom nuclear plants, a kilogramme of uranium was worth 56 dollars.

The tendency towards lower prices for fissionable materials is continuing, usually as a result of direct administrative intervention. Thus, on 29 May 1961, the United States Atomic Energy Commission announced that prices would be cut by 20 to 40 per cent, depending on the particular case, and that various bureaucratic controls would also be lifted.5/

In the case of nuclear plants, current fuel costs are about 0.3 dollar cents per kWh. It is hoped to reduce them by 30 per cent in the next five years, and by as much as 50 per cent in certain cases.6/

As regards conventional thermal plants, a good example to take is the Dock Sud plant of 600 MW in Greater Buenos Aires. The specific consumption foreseen for it is 2,500 calories per kWh at a cost of 2 dollars per million calories of fuel (fuel oil),7/ i.e. at a cost of 0.5 dollar cents per kWh under this head.

If, in order to save 0.002 dollars per kWh in fuel through the use of nuclear plants, the initial investment has to be 50 per cent larger, it is easy to deduce from the general formula what capital charge coefficient - with a given utilization factor -, would tip the balance one way or the other, or to express the equation in terms of any other variable whose behaviour is of particular interest.

Generally speaking, in fact, nuclear plants in the next decade will be uneconomic except in areas with high electricity consumption - where plants of 50 MW or over could be established - and high conventional fuel costs.8/

5/ New York Times, 30 May 1961.

6/ IAEA op.cit.

7/ See Estudio Económico, Centrales Eléctricas de Agua y Energía, Buenos Aires, November 1959.

8/ The probable floor specified by the IAEA is 2.20 dollars per million calories, given a capital charge coefficient of 0.14 and a plant factor of 80 per cent.

/If the

If the capital charge coefficient were to decline from 0.14 to 0.07, i.e. within the range permitted by the Federal Energy Commission to concessionary companies in the United States, the price ceiling for conventional fuel would drop to 1.80 dollars per million kW.

There are few parts of Latin America that unite the conditions described and that would increase the economicity of nuclear plants. Moreover, adequate water resources are non-existent. One of these areas is the north of Chile, where industrial demand is high and fuel oil costs over 20 dollars a ton.[9/]

Mention has also been made of the Mambucaba nuclear plant in Brazil, which, if incorporated into a system with a capacity of more than 4 million kW, would, by occupying the base of the load diagrams, enable a high degree of utilization to be reached.[10/]

9/ See E. Friedmann, "Aplicación económica de la energía nuclear", El Mercurio, 24 June 1961, in which the case of the north of Chile is examined. For more details on various cases, see the Organization of American States, Tercer Simposio sobre Aplicación Pacífica de la Energía Nuclear, Petrópolis, July 1960.

10/ See Carlos Vélez, Criteria for the addition of nuclear power stations to existing electricity systems (ST/ECLA/Conf.7/L.4.3).