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EXPERIENCE ACQUIRED IN EUROPE IN THE INTEGRATION AND CO-ORDINATED OPERATIONS OF NATIONAL ELECTRIC POWER NETWORKS

Report prepared by the Energy Division of the United Nations Economic Commission for Europe

Note: This text is subject to editorial revision.

CHAPTER I : CHARACTERISTICS OF ELECTRIC POWER PRODUCTION IN EUROPEAN COUNTRIES

(a) Geographical distribution of natural energy sources in Europe

Natural sources of energy in Europe are geographically divided into three groups:

- a northern region comprising, from west to east, Ireland, Northern Scotland, Norway, Sweden and Northern Finland.
- a southern region comprising the Iberian peninsula, southern and south-western France, Switzerland, Austria, Italy and western Yugoslavia.
- a central region between the other two regions.

The resources of the first two regions are mainly hydraulic. Coal is found only in a few scattered deposits such as those in Spitzbergen and southern Sweden in the northern region, and in Spain in the southern region. The southern region also has deposits of lignite in Yugoslavia, and of gas and petroleum in France, Italy and Yugoslavia, and geothermal energy sources in Italy. In the northern region there are large deposits of peat, mainly in southern Sweden and Finland, but these are little exploited.

The resources of the central region consist almost entirely of solid fuels; the coal fields of Great Britain, Belgium, the Netherlands, Silesia, the Ruhr and northern France may be mentioned in particular. There are also extensive lignite deposits, mainly in Germany, Poland, Czechoslovakia, Austria and Hungary. The hydro-electric potential of the central region is low except in eastern Yugoslavia and Romania, which also has large deposits of petroleum and natural gas.

An inventory of energy resources available in European countries is given in Table 1, while Table 2 1/ gives additional information on these resources per capita. This information shows the basis of the power economy of the countries concerned.

(b) Relationship between hydro-electric and thermal power production in Europe

It must be pointed out, first of all, that Europe's electric power requirements are met exclusively by the production of hydro-electric and thermal plants. In 1959 the production of nuclear power plants still represented only 0.15% of these requirements.1/ Among the sources of energy which may be regarded as new, wind power is used only for isolated installations, and the use of geothermal energy is confined to certain countries, such as Italy and Iceland.

1/ Excluding the USSR.

/Table 3

Table 3 shows the present distribution of installed capacity and of electric power production as between thermal and hydro plants. It will be noted that in Norway and Switzerland, for example, production is almost entirely hydraulic. The proportion of hydro power is also very high in Austria, Ireland, Italy, Portugal and Sweden, whereas thermal power predominates in Hungary, the Netherlands, Poland and the United Kingdom. In France and Czechoslovakia production is divided about equally between hydro and thermal plants.

Hydro plants in Europe may be divided into three groups:

- plants in high mountains, using a relatively high head of water and equipped with large reservoirs;
- run-of-stream plants using a low head, without reservoirs;
- plants using a medium head, with reservoirs of relatively low capacity.

In each of the countries in which hydro power production predominates, such as Norway, Switzerland, Austria, Italy, Portugal and Sweden, there are plants of these three kinds. It is the differences in their operating conditions which have long made it necessary to interconnect them.

In 1959, 60% of the fuel burnt by European thermal plants was coal. Additional information on this subject is given in Table 4 which also shows the part played in the different countries by other sources of energy, viz.: lignite, petroleum products, natural gas, manufactured gas and peat.

/CHAPTER II

CHAPTER II : DEVELOPMENT OF INTERCONNEXION IN EUROPEAN COUNTRIES

(a) Development of the organization of electric power services in Europe

In most European countries, the initiative in the exploitation of electric power was provided by private enterprise.

In some cases industrial undertakings built electric power plants for their own needs and sold part of the electricity produced, mainly for lighting purposes, in the vicinity.

In other cases, the initiative was taken by private undertakings, whose purpose was to exploit an electric power plant. As the construction of distribution networks to bring the electricity to the consumers required the authorization of municipalities, they were often obliged to provide this service themselves. This led to the establishment of municipal electric power undertakings, operating distribution networks supplied with power either by private enterprise or by their own plants. These distribution networks developed rapidly in urban centres, but in most European countries electricity was not introduced in rural districts until much later. It was at this second stage that in order to supply electricity to a number of local networks, regional distribution systems supplied by more powerful plants were constructed. Then the local or regional authorities of some countries began to take an interest in the development of electrification and in some cases set up their own electric power undertakings. Still later, in a number of European countries, the State itself undertook the supply of electric power, the method of operation of this nationalized service varying from country to country.

(b) Objectives of the interconnexion of electric power plants

Initially, the main purpose of interconnecting lines and of sub-stations linking two adjacent networks was to provide for mutual assistance in case of emergency or compensating supplies of power during periods of water shortage.

The interconnexion lines used were of relatively low capacity and operation in parallel was rare; the arrangement consisted mainly of separating part of one network and connecting it to another or connecting separate groups to a network with insufficient power.

/This method

This method had the disadvantage of causing interruptions in the supply, however, to overcome which, groups of two or more networks gradually came to be operated in parallel on a permanent basis. This mode of operation, which became possible after certain procedures were agreed on for regulating the frequency and capacity of exchanges, greatly increased the reliability of the supply, so that the reserve capacity of the interconnected systems could be reduced.

At the present time, as a result of the operation of large systems in parallel, interconnexion provides an effective means of:

- providing an uninterrupted supply even in the event of failure of certain lines or of a breakdown of generator sets;
- reducing the installed capacity of the plants required to meet consumers' needs, with a consequent saving in investment;
- concentrating capacity in larger plants, equipped with a relatively smaller number of large generator sets;
- co-ordinating the operation of all plants feeding the interconnected network, i.e. reducing lost water in hydro plants and fuel costs in thermal plants.

(c) Development of interconnected networks in European countries

In Europe, before the Second World War, nation-wide interconnected networks existed only in Ireland and the United Kingdom. At that time the larger plants in those countries were already being operated in parallel and were co-ordinated by a central distribution station. During the same period interconnexion was being developed in Germany, Belgium, France, and Sweden.

At the present time, most European countries have completed the interconnexion of their networks and in the near future all plants will be operated in parallel and co-ordinated by distribution stations provided with modern remote reading, remote control and telecommunication equipment.

/CHAPTER III

CHAPTER III : DEVELOPMENT OF INTERCONNEXION BETWEEN NATIONAL ELECTRIC POWER TRANSMISSION NETWORKS

(a) Objectives of international exchanges of electric power

The advantages of interconnecting electric power transmission networks at the national level were explained in the preceding chapter. These advantages depend on the total capacity interconnected, and it is therefore understandable that European countries should have tried gradually to co-ordinate the operation of their own individual networks by interconnecting them.

In such countries as Belgium, Denmark, the Netherlands, Poland and the United Kingdom, where electric power is generated almost exclusively by thermal plants, national co-ordination of the operation of plants linked to the interconnexion network is necessarily confined to securing optimum load distribution among production units, according to their output. In countries where production is almost exclusively hydraulic, such as Austria, Norway, Switzerland and Sweden, national co-ordination of operation is confined to avoiding loss of water, so far as possible, by using the production of run-of-stream plants for normal loads and that of storage plants for peak loads. France, on the other hand, whose electric power production is divided about equally between thermal and hydro plants, can take advantage of the differences arising out of the mode of operation of these two types of plant. It is this same advantage which is derived from the interconnexion of national networks.

Another aspect of the integration of national networks is the construction of power plants. Efforts to reduce power plant construction and operating costs have led to the use of increasing by powerful units. Hence, the total installed capacity is increasing by relatively large steps and is liable to exceed national requirements, at least temporarily. This situation has led certain neighbouring countries to co-ordinate their building programmes, in order to benefit by electric power exchanges. More generally speaking, the co-ordinated operation of national networks, when these are interconnected, means movements of electric power between them.

In this connexion, the following five types of exchange should be distinguished:

/-. guaranteed contractual

- guaranteed contractual supply
- contractual supply as required
- guaranteed exchanges
- occasional exchanges
- emergency supplies.

Guaranteed power supplies are usually made under long-term contracts which serve as a basis for the power supply programme of the importing country. In addition to stipulating the quantities and capacity of the supply, such contracts often provide for the joint construction of power plants and interconnexion lines.

Supplies "as required" are supplies which one country may make available to another for as long as its power situation permits. Such arrangements can be suspended at short notice in the event of any unforeseen change in the operating conditions of the exporting country.

Guaranteed exchanges are generally based on variations in hydraulic conditions; countries producing hydro power can undertake to make a certain quantity available in summer to countries which depend on thermal production, in exchange for winter supplies. This makes it possible to concentrate maintenance work on thermal plants during the summer and to assist countries depending on hydro power during the winter, particularly during periods of water shortage.

As their name indicates, occasional exchanges are carried out over very short periods - sometimes only a few hours. Their advantage is that they can be arranged at short notice. They are used, for example, to avoid loss of water in hydro power systems when the national market is saturated, and result in substantial savings of fuel in countries which rely on thermal power production.

Lastly, emergency supplies are provided as mutual assistance between neighbouring countries in the event of breakdowns causing an unforeseen reduction in the amount of power available.

(b) Development of frontier-crossing lines

The process of interconnexion, which began with power plants situated near one another, was extended to the regional networks so formed. Movements of electric power between such regional networks soon made it necessary to increase the capacity of transmission lines and to use higher and higher voltages.

With the interconnexion of national networks, the amounts of power to be transmitted reach an ultimate limit; what is required, therefore, is not

/necessarily the

necessarily the construction of special high-voltage transmission lines but rather connexion of the terminal points of the national networks on either side of the frontier.

The transmission of electric power across an intermediate country is effected by "load slipping", i.e. the agreed amount of power is delivered by the exporting country to the point at which its network is connected with that of the intermediate country, which in turn delivers that amount to its point of connexion with the network of the importing country. With due allowance for some reduction due to assumed or real losses in transmission, the power initially exported is ultimately used by the network of the intermediate country.

The capacity and the number of interconnexion lines have developed side by side with those of national network lines. Table 5 shows the frontier-crossing interconnexion lines in service at 1 January 1959. Table 6 gives data on the lines put into service between February 1952 and 31 December 1959, from which it can be seen that continuous progress is being made in linking up European networks.

(c) Development of international electric power exchanges

Table 7 shows the exchanges of electric power between European countries in 1959. These exchanges represent 1.4% of the total electric power produced in the countries concerned. However, the volume of these exchanges is steadily increasing at a faster rate than electric power production; this can be seen, in particular, from Table 8.

In 1951 the Union for Co-ordinating Production and Distribution of Electricity (UCPTE) [7] was set up with a view to securing optimum utilization of the means of production and transmission of electricity then existing or to be provided in the future, in the following countries: Western Germany, Austria, Belgium, France, Italy, Luxembourg, the Netherlands and Switzerland. To this end the Union has endeavoured, in particular, to facilitate and expand international exchanges of electric power. In 1953 the countries members of the Union adopted special rules designed to lift restrictions on certain categories of electric power exchanges, within previously fixed limits. In 1956 the rules were extended to apply to seasonal supplies and the quota system was also abolished [22]. This and other measures taken by UCPTE, such as those designed to secure quick exchange of information on the situation of countries interested in importing or exporting electric power, have resulted in a rapid increase in exchanges between countries

/members of

members of the Union. Table 9 shows that the consumption of electricity in the member countries as a whole has almost doubled in eight years, while exchanges between them have almost trebled during the same period.

Table 9

Consumption of electric power by the group of 8 countries members of UCPTE and exchanges between them

Year	Imports in 10^6 kWh	Total consumption in 10^6 kWh	Imports as % of total consumption
1950	2954	132492	2.2
1951	3873	153700	2.5
1952	4045	165921	2.4
1953	4158	174711	2.4
1954	5235	191231	2.7
1955	5697	209986	2.7
1956	6971	223677	3.1
1957	8254	240110	3.4
1958	8247	257111	3.2

The bulk of these exchanges were long-term operations such as supplies under an agreement between firms of two different countries on the joint construction and operation of a power plant or, to give another example, seasonal exchanges of power guaranteed by contracts between thermal power and hydro power producing countries. The remainder consisted of occasional exchanges, make-up supplies and emergency supplies. Although the volume of such exchanges is relatively small, they are of real value in the electric power economy of the countries concerned.

/The advantages

The advantages of such arrangements can be seen from the following examples of co-operation between countries members of UCPTE in the past:

- The power shortage which occurred in Western Germany in the winter of 1953/54 was effectively remedied by supplies from Belgium, France, Italy and the Netherlands.
- In the same winter, during a period of extreme drought in the central and northern Alps, while water conditions were favourable south of the Alps, Italy was able to come to the aid of Switzerland and Austria and make up the hydro power shortage in those countries.
- During the winter of 1955/56 the scarcity of water in the Alps caused a marked shortage of hydro power in Switzerland. To overcome those difficulties an extensive programme of assistance by the thermal production countries was organized. This enabled Switzerland to provide for as much as 40 per cent of its night consumption and 15 per cent of its day consumption by imports. The capacities involved were 240 MW from the Federal Republic of Germany, 45 MW from Belgium, 50 to 100 MW from France and 30 to 60 MW from the Netherlands.
- A similar situation occurred in the winter of 1959/60: assistance from interconnected countries enabled Austria, normally an exporting country, to import about 10 per cent of its requirements on 19 January 1960. Switzerland imported 23 per cent of its requirements for several days in November 1959, and in February 1960 its total imports reached about 15 per cent of consumption.

/CHAPTER IV

CHAPTER IV: TECHNICAL CONDITIONS REQUIRED FOR THE INTERCONNEXION OF NATIONAL NETWORKS

(a) Installations for the interconnexion of networks

In many cases the interconnexion of two networks is effected merely by erecting a line linking two connexion stations fairly near the frontier on either side.

If the two networks use the same voltage, a relatively simple extension from the existing stations is usually all that is needed. These stations must, however, be equipped to measure the active and reactive power exchanged and often by means of remote reading devices - to follow their fluctuations at a control point. If two networks using the same voltage are directly interconnected, the same method of earthing the neutral points must be used.

If the voltage of the two networks are different, a coupling transformer is essential. It may be a transformer with two separate windings or an auto-transformer; in the latter case the neutral points of the two networks to be interconnected must be earthed direct. In any case the coupling transformer should be adjustable between wide limits so that the voltage can be regulated to avoid transmission of reactive power.

As the interconnexion line makes it possible to obtain assistance from another network instantaneously in case of a breakdown, the connexion between the networks should be maintained as long as is possible without risk of damage to equipment. Interconnexion lines should therefore be adequately protected to prevent the circuit being broken too quickly in the event of serious disturbances caused by short circuits of long duration. For this reason, ultra-rapid protective devices with phase selection and automatic re-closing are often used to protect international interconnexion lines.

(b) Earthing of neutral

The choice of the method of earthing the neutral is closely linked with the choice of the method of protecting the lines. If choke coils are used, a relatively slow-acting line protection system, without automatic re-closing, can be adopted. On the other hand, direct earthing often requires quick-acting line protection with automatic re-closing in order to secure stable operation.

The interconnexion of two or more networks equipped with coils, however, raises the problem of increased residual current which may exceed the limit of automatic extinction. In such cases the two networks must be separated by a transformer or some other system must be adopted.

/Separation by

Separation by a transformer also appears to be the best method where the two interconnected networks are at the same voltage, but one is equipped with coils, whereas the neutral of the other is connected direct to earth. If the transformer is adjustable, so that the power can be regulated, its use is preferable to other systems such as the introduction of an adjustable homopolar reactance or an ultra-rapid protection device with automatic re-closing.

(c) Regulation of frequency and power

The interconnexion of networks raises a number of problems with regard to regulation of the generating plant in service.

In most cases the power at which the electricity is to be exchanged is fixed by agreement. Maintaining the power at the agreed level calls for a certain amount of care in regulating operations.

Where the capacities of the networks differ very greatly it is sometimes agreed that the one with the higher capacity shall maintain the frequency at a specified value. The other networks connected to it must then regulate their production on the basis of that frequency so as to maintain the power level for exchange with the principal network.

This method of control has the disadvantage, however, of obliging the network responsible for maintaining the frequency to compensate for each variation in the overall load of the interconnected networks pending their adjustments. This considerably increases regulation operations by the principal network.

The method known as "frequency-power" or "energy-phase" regulation provides a means of overcoming these difficulties, since it obliges each interconnected network to adjust for its own load variations.

"Frequency-power" regulation is the method mainly used in western Europe, where most networks have been provided with automatic equipment for this purpose.

(d) Other technical problems

In order to prevent the transmission of reactive current, which is often prohibited in arrangements for interconnected operation of two networks, voltage regulation devices and apparatus for measuring reactive current are required. Regulation is usually effected by means of a transformer equipped with a remote control device for regulation under load.

/If two

If two networks can be interconnected at several points or if several networks can be interconnected with one another, the problem of ring operation arises. This arrangement makes it possible to maintain the interconnexion even when one of the lines linking two networks is disconnected.

Furthermore, when several networks are operating in a ring, a circular current is superimposed on the current representing the agreed power exchanges. This current tends to reduce overall losses, which is an additional advantage. But although this circular current reduces the absolute current in some circuits, it increases it in others and may thus cause overloads. The circular current can, of course, be reduced by introducing phase shifting devices, but such equipment is very costly. If the ring is large enough there is no danger of overloading, but it is recommended that before a ring is formed, the possible effects should be studied by means of a model network.

/CHAPTER V

CHAPTER V: CONDITIONS FOR THE ORGANIZATION AND CO-ORDINATED OPERATION OF SEVERAL NATIONAL NETWORKS

(a) Exchange of information, conclusion of exchange agreements and supervision of operation

Interconnected operation of two or more national networks presupposes the existence of a national distribution station or at least a regional station responsible for operational relations with foreign networks. This station must be equipped with remote reading and control devices with which to supervise power exchanges with foreign countries and to regulate these exchanges according to the agreed programme. The station must also have direct telephone connexions.

If the power exchanges are to be of short duration and to take place without notice, the distributors of the two countries concerned must be authorized to make offers and conclude short-term contracts on their own initiative. Thus, a number of countries have agreed to liberalize their imports and exports of electric power within certain limits of quantity and duration, under arrangements authorizing the automatic transfer of currency to cover the cost of the electric power exchanged. [22]

The distributors of the national networks must, in the first place, be kept regularly informed of production conditions on the interconnected networks. For this purpose the UCPTE has developed a system for the rapid collection of information on the exchanges made, the amount of water lost and the situation of the different countries as importers or exporters. This information is immediately circulated to the national distributors concerned by teletype.

The experience acquired in the eight countries members of UCPTE shows, in particular, that there is no need to set up an international distribution centre [9] for co-ordinated operation, even if the total installed capacity of the networks exceeds 30,000 MW.

(b) Co-ordination of maintenance plans

Every power plant requires certain maintenance work from time to time, for which purpose one or more generator groups have to be shut down for some length of time. In the case of countries producing hydro power, such work is generally timed according to probable flow, in order to avoid waste.

The repair schedules for thermal power plants depend mainly on fluctuations in peak daily demand throughout the year. To ensure dependable operation, a

/certain reserve

certain reserve power must be maintained throughout the year, for relief operation in the event of breakdown or failure. Before national systems were interconnected such repair work used to be spread over the whole year.

Interconnexion has permitted effective co-operation between hydro power and thermal power producing countries. Maintenance work on thermal plants can be concentrated in the summer while a part of their load is covered by imports of hydro power; in this way the overhaul of the plants in winter can be avoided and power can be supplied to the hydro power producing countries. A special group has been set up in the UCPTE to draft a schedule for overhauls [5]. This group has prepared, in particular, recommendations for reducing the time consumed by overhauls [14]. In addition, it has studied the question of the minimum technically feasible rate of operation and the rapid controlled starting of thermal plants and precautions to be observed in the commissioning of new thermal units [16] [19].

(c) Measurement of amounts of electric energy exchanged and accounting methods

In Europe, contracts for electric power exchanges are invariably bilateral. In cases where one country supplies power to another through the network of an intermediate country, remuneration in kind is usually agreed on in respect of the use of the intermediate network and also in respect of the losses occasioned.

Contracts relating to exchanges of electricity generally stipulate the quantity to be supplied and the power at which it is to be delivered. They contain, in addition, clauses regarding the establishment of daily or weekly supply schedules, the discontinuance of supply in case of a drop in frequency, and the control of reactive power.

Accounting records of the quantities of energy supplied are generally kept on both sides of the frontier, the quantity exchanged being determined by the arithmetic mean of the meter readings, the costs representing losses on the interconnexion line being shared.

The power at which electricity is exchanged between two systems is always subject to rapid fluctuations of varying amplitude. These fluctuations depend upon the capacities of the machines in use, the nature of the load and the control devices used. As a rule, they do not affect operations and there would be little point in trying to eliminate them. Accordingly, the power at which electricity is exchanged should be measured, for accounting purposes, by a method which ignores these fluctuations. This is often done by means of special meters which record the average power at five, ten or fifteen-minute intervals.

/Irrespective of

Irrespective of the precautions taken to control the power at which the electricity is exchanged, it is impossible to adhere precisely to the established schedules. For accounting purposes, however, if the programme is carried out in the normal way, without interruptions due to breakdowns and at a sufficiently stable frequency, the simplest course is to consider that the schedule has been observed. The gap between the schedule and actual performance is then entered in an "involuntary exchanges" account. These may be paid for in a number of ways. In some cases a price per kWh during the day and at night is agreed upon, while in others it is agreed to settle the balance by a supply of electricity at low power.

If, however, the frequency is not very stable, or if the automatic frequency regulating equipment is more efficient in some countries than in others participating in the co-ordinated operation, gaps which tend to check fluctuations in frequency may be rewarded whereas those which increase these fluctuations may be penalized. On these lines, the UCPTE has worked out an accounting system which makes allowance for the performance of each of the interconnected systems [17].

In the case of the operation of several systems in a loop circuit the problem is still more complicated, since in addition to the scheduled supplies there is a "loop transit" which reduces the losses - though not, unfortunately, evenly. Hence, where a loop circuit is used, the sum by which the profits exceed the losses of the interconnected systems as a whole has to be apportioned. A UCPTE working party [17] is working on rules which would give sufficiently accurate results with the use of a simplified method of calculation.

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Table 1

INVENTORY OF MAXIMUM AVAILABLE ENERGY RESOURCES IN EUROPE (EXCLUDING USSR) AND THE USSR

Country	Hard coal (normally proved and probable to 1 200 m) (10^6 metric tons)	Brown coal and lignite (total geological reserves) (10^6 metric tons)	Peat (probable) (10^6 metric tons)	Petroleum (proved and probable) in 10^6 metric tons (including est. oil-content of oil-bearing shales in parentheses)	Natural gas (reserves in producing fields) (10^6 m^3)	Hydro-electric power (exploitable possibilities) (10^6 kWh/year)	Other (including non-conventional resources: Wind-power = W, Tidal = T, Geothermal = G, Fuel wood a/ = F) (in 10^6 kWh/yr)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Albania	...	...	-	3.0	...	5 000	-
Austria	4	290	80	95.0b/	17 500	40 000	-
Belgium	5 988c/	-	-	-	...	545	-
Bulgaria	42	3 500	...	2.0	-	11 100	-
Czechoslovakia	6 000	7 300	-	1.0	3 000	12 000	-
Denmark	-	30	690	-	-	50	-
E. Germany	162	30 455	...	-	...	2 000	-
Finland	-	-	11 000	-	-	17 000	1 300(F)
France	8 413	420	-	5.9(+125)	300 000	76 270	(21000(T) (95000(W)
Greece	...	3 000	-	-	-	4 260	-
Hungary	20	2 520d/	...d/	16.4	3 700	3 350	-
Iceland	-	-	2 000	-	-	35 000	2 500(G)
Ireland	18	-	3 500	-	-	1 050	-
Italy	500*	430	-	20.0	130 000	55 000	2 750(G)
Luxembourg	-	-	-	-	-	65	-
Netherlands	3 400	10	30	16.5	...	-	-
Norway	...e/	-	80*	-	-	104 500	-
Poland	135 000	33 000	5 900	2.7f/	4 000	13 300	-
Portugal	28	30	...	-	-	13 200	-
Romania	48	2 480	68	80.0g/	246 000	27 000	-
Saar	8 000	-	-	-	-	30	-
Spain	8 000	1 500	...	-	-	31 500	-
Sweden	100	-	9 400	(250)	-	80 000	1 400(F)
Switzerland	-	-	-	-	-	32 300	-
Turkey	1 500	280	-	10.0	...	90 000	-
United Kingdom	170 680	-	600	(16)	-	11 470	(2360(T) (4-10000(W)
W. Germany	224 300	63 000	9 840	65.0	35 000	25 165	-
Yugoeslavia	230	21 360	...	56.0	18 000	66 500	-
Total (of data shown) Europe (excluding USSR)	572 333	169 605	43 098	373.5(+391)	757 200	757 655	-
USSR	1 320 000	211 090	...	3230(+8950)	985 000	1 500 000	-

a/ Calculated as electricity equivalent of available fuel wood and wood waste in countries with resources exceeding 20 x 10^6 m^3 per year piled measure
b/ Proved reserves (1956).
c/ 4254 x 10^6 tons in active consessions to depth of 1 500 m.
d/ Peat is included under brown coal.
e/ Deposits in Spitzbergen.
f/ An alternative estimate suggests a possible reserve of about 4 x 10^6 metric tons.
g/ Proved reserves (1 January 1955).

Table 2

COMPARISON OF ESTIMATED PRIMARY COMMERCIAL ENERGY RESERVES IN EUROPE RELATIVE TO POPULATION

(Countries arranged in increasing order of column 9)

Country	Solid mineral fuels (maximum known reserves in metric tons/inhabitant) a/		Liquid and gaseous fuels (provisional reserves in tons/inhabitant a/ and m³/inhabitant a/ respectively)		Maximum exploitable hydro power (10³kWh/inhabitant) a/	Commercial Energy Reserves per inhabitant a/ in electricity equivalent		
	Hard coal	Brown coal and lignite	Petroleum	Natural gas		10⁶ kWh per inhabitant a/ at full calorific equivalent b/	of which percentage represented by hydro power x 1000	10⁶ kWh per inhabitant a/ with fuels converted at 25% efficiency
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Denmark	-	7	-	-	.01	.03	40	.02
Hungary	2	257 c/	1.7	377	.34	1.02	33	.51
Netherlands	316	1	1.5	...	-	2.55	-	.64
Greece	-	376	-	-	.53	1.47	36	.77
Ireland	6	-	-	-	.36	2.82	13	.97
Italy	10	9	0.4	2 705	1.14	1.28	89	1.18
Eastern Germany	9	1 697	-	...	.11	4.43	3	1.19
Belgium-Luxembourg	675	-	-	...	.06	5.29	1	1.37
Portugal	3	3	-	-	1.51	1.54	98	1.51
Spain	276	52	-	-	1.09	3.43	32	1.67
Romania	3	141	5.0	13 994	1.55	2.14	73	1.70
Bulgaria	6	464	.3	-	1.47	2.68	55	1.77
France	195	10	0.1 (2.9)	6 900	1.76	3.45	51	2.18
Czechoslovakia	458	558	0.1	229	.92	5.98	15	2.18
Albania	...	...	2.0	...	...	3.65	99	3.63
Turkey	62	12	0.4	...	3.73	4.26	88	3.86
Finland	-	-	-	-	4.01	4.01	100	4.01
Yugoslavia	13	1 212	3.1	1 021	3.77	6.96	54	4.57
Austria	1	42	13.6	2 510	5.74	6.03	95	5.81
Switzerland	-	-	-	-	6.49	6.49	100	6.49
United Kingdom	3 354	-	(0.3)	-	.22	27.02	1	6.92
Western Germany	4 395	1 236	1.3	686	.49	37.90	1	9.84
Poland	4 950	1 210	0.1 d/	147	.49	43.11	1	11.14
Sweden	14	-	(34.0)	-	11.02	11.54	96	11.15
Saar	8 163	-	-	-	.03	64.55	-	16.16
Norway	e/	-	-	-	30.51	30.51	100	30.51
Europe (excl. USSR)	1 320	393	0.9(.9)	1 760	1.80	13.33	13	4.59
USSR	6 590 *	1 055*	16.2(34.8)*	4 930*	9.60*	65.77*	15*	24.19*

a/ Related to population as at 1955. Figures in parentheses in column 4 refer to estimated oil content of oil-bearing shales.
b/ Fuels converted at the following rates: Hard coal 8.0 kWh/kg, Brown coal and lignite 2.5 kWh/kg, Petroleum 12.0 kWh/kg and Natural gas 10.6 kWh/m³. An allowance for estimated oil content of oil-bearing shales is included where appropriate.
c/ Peat included.
d/ An alternative estimate suggests a somewhat higher reserve.
e/ Data for deposits in Spitzbergen not available.

Table 3

Capacity and annual production of thermal and hydro-electric plants in European countries

Country	Maximum capacity in MW		Net production in 1959 in 10^6 kWh			Total hydro-electric production as percentage of total production in 1959
	Thermal plants	Hydro-electric plants	Thermal	Hydro-electric	Total	
Albania	..	..				
Austria	1,118	2,975	3,815 a/	10,975 a/	14,790 a/	74
Belgium	3,443	48	13,097	100	13,179	1
Bulgaria	..	..	..	..	..	..
Czechoslovakia	..	..	18,449	2,026	20,468	14
Denmark	1,660	9	4,341	25	4,366	1
E. Germany	..	..	..	..	..	..
Finland	..	..	..	..	..	..
France	9,790	9,142	32,000 b/	32,613	64,613	50
Greece	438	111	..	..	..	..
Hungary	1,202	17	6,351	77	6,428	1
Iceland	30	110	22 a/	477 a/	499 a/	96 a/
Ireland	425	219	1,258	739	1,997	37
Italy	3,993	10,768	10,690 a/ c/	38,370 a/	49,060 a/	78 a/
Luxembourg	254	1	1,300	3	1,303	–
Netherlands	4,490	–	14,178	–	14,178	–
Norway	150	5,530	255	28,375	28,630	99
Poland	4,615	245	23,581	547	24,128	2
Portugal	190	1,030	124	2,847	2,971	96
Romania	1,510	100	6,503 a/	299 a/	6,802 a/	4 a/
Spain	..	4,281 P	..	..	..	..
Sweden	1,986	6,740	3,370	28,622*	31,992*	90*
Switzerland	180	5,240	103 d/	18,078 d/	18,181 d/	99 d/
Turkey	829	351	1,710	685	2,395	3
USSR	46,420	12,617	200,600	47,400	248,000	19
United Kingdom	31,299	1,157	111,936 b/	2,693	114,629	2
Western Germany	20,200	3,185	85,559	10,912	96,471	11
Saar	604	4	2,734	19	2,753	1
Yugoslavia	563	1,134	3,071	4,685	7,756	60

NOTE: The figures in this table have been supplied directly by governments.
(a) Gross production
(b) Including nuclear production: 41 x 10^6kWh for France; 1201x10^6kWh for the United Kingdom
(c) Including geothermal production (2080 x 10^6kWh)
(d) Hydrological year (1 October – 30 September) including production of nuclear plants.

Table. 4

Annual consumption of fuel for electric power production in selected European countries in 1958

(in 10^9 Kcal)

Country	Hard coal		Lignite	Peat and fuel wood	Liquid fuels	Natural gas	Manu-factured gas	Other fuels	Total con-sumption
	Calorific value exceeding 4,500 kcal/kg	Calorific value below 4,500 kcal/kg							
Austria	376	-	4,364	-	1,569	2,753	736	445	10,243
France	35,605	35,473	1,229	-	8,183	208	15,900	-	96,598
Greece	-	-	2,536	-	2,300	-	-	-	4,836
Hungary (a)	3,329	13,521	5,060	-	491	-	-	-	22,401
Italy	5,757	510	1,396	-	9,860	3,950	1,370	22	22,865
Luxembourg	-	-	-	-	15	-	4,672	-	4,687
Norway	-	-	-	-	505	-	-	-	505
Netherlands	34,860	-	-	-	4,150	-	481	125	39,616
Poland	83,594	-	2,029	-	173	-	1,939	-	87,735
W. Germany (a)	73,200	-	68,200	560	1,570	100	670	-	144,300
Saar	872	7,891	-	-	4	-	1,996	-	10,763
Turkey	1,668	1,635	1,960	-	640	-	189	62	6,154
United Kingdom	325,425	-	-	-	26,429 (b)	-	-	146	352,000 (b)
USSR (a)	152,825	31,800	109,360	35,435	20,697	60,742	1,240	-	412,099
Yugoslavia	242	4,579	6,376	-	64	-	53	-	11,314

(a) Public utilities only

(b) For liquid fuels, public utilities only

Table 5

Frontier-crossing lines in service at 1 January 1959

Countries connected		Interconnexion lines	
1	2	Voltage kV	Total number of circuits
Austria	W. Germany	380	2
"	"	220	6
"	"	110	15
Austria	Italy	110	2
Austria	Yugoslavia	110	1
Austria	Czechoslovakia	220	2
Belgium	France	150	3
Belgium	France	63	1
Belgium	Luxembourg	65	2
Belgium	Netherlands	220	1
"	"	150	2
Belgium	W. Germany	220	1
Bulgaria	Romania	60	2
Czechoslovakia	Hungary	110	4
Czechoslovakia	Poland	110	1
Denmark	W. Germany	60	1
Denmark	Sweden	50/120	3/2
France	Luxembourg	63	2
France	W. Germany	225	1
"	"	150	2
"	"	110	2
France	Italy	225	1
"	"	63	5
France	Switzerland	225	3
"	"	150	8
"	"	125	1
"	"	63	1
France	Andorra	60	1
France	Spain	220	1
"	"	150	1
"	"	110	1
Italy	Switzerland	220	3
"	"	150	2
"	"	130	6
"	"	50	1
Netherlands	W. Germany	220	1
Poland	E. Germany	100	1
Portugal	Spain	130	1
Spain	Andorra	110	1
Switzerland	W. Germany	220	1
"	"	380/110	1/3
"	"	220/110	2
"	"	110	2
Yugoslavia	Hungary	120	1
Yugoslavia	Italy	110	1
"	"	50	1

Table 6

Progress in international interconnexion in Europe (110 kV or above) between February 1952 and December 1959

Countries connected		Interconnexions		
1	2	Voltage kV	Total number of circuits	Year brought into service
Austria	Italy	220	1	1953
"	Western Germany	110	4	1953
"	" "	220	2	1955
"	" "	380 a/	1	1956
"	" "	380 a/	1	1957
"	Switzerland	110	1	1959
"	Czechoslovakia	220	2	1958
"	Yugoslavia	110	2	1955
Belgium	Netherlands	150	1	1955
"	"	150	1	1958
"	France	150	1	1957
Czechoslovakia	Poland	110	1	1956
"	"	220	1	1959
Denmark	Sweden	120	1	1953
"	"	120	1	1954
"	"	120	1	1958
Eastern Germany	Poland	110	1	1956
Finland	Sweden	220	1	1959
France	Italy	220	2	1956
"	Spain	225	1	1953
"	"	150	1	1956
"	Switzerland	225	2	1955
"	"	225	1	1956
"	"	225	1	1957
"	"	150	2	1954
"	"	150	1	1956
"	Western Germany	220	1	1952
"	" "	150	1	1953
"	Western Germany (Saar)	220	1	1958
"	" "	150	2	1958
Hungary	Yugoslavia	120	1	1958
Italy	Switzerland	220	1	1952
"	"	220	2	1953
"	"	220	2	1956
"	"	220	2	1957
Norway	Sweden	220	1	1959
Portugal	Spain	220	1	1958
Western Germany b/	Switzerland	220	1	1957
" "	"	220	1	1958

a/ Provisionally brought into service at 220 kV

b/ See also Austria and France

Table 7

INTERNATIONAL EXCHANGES OF ELECTRIC ENERGY DURING 1959 a/ (10^6 kWh)

Exporting countries \ Importing countries	Albania	Austria	Belgium (p)	Bulgaria (p)	Czechoslovakia	Denmark	Eastern Germany (p)	Finland (p)	France	Hungary	Ireland	Italy	Luxembourg	Netherlands	Norway	Poland	Portugal	Romania	Spain (p)	Sweden	Switzerland	United Kingdom	USSR	Western Germany	Saar	Yugoslavia	Exports (total)	Exports as percentage of national production
Albania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Austria	-		-	-	110	-	-	-	-	-	-	80	-	-	-	-	-	-	-	-	-	-	-	2332	-	10	2532	17.1
Belgium	-	-		-	-	-	-	-	85	-	-	-	19	25 b/	-	-	-	-	-	-	-	-	-	72	-	-	201	1.5
Bulgaria	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Czechoslovakia	-	34	-	-		-	1	-	-	304	-	-	-	-	-	34	-	-	-	-	-	-	-	-	-	-	373	1.8
Denmark	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	301	-	-	-	60	-	-	361	8.3
Eastern Germany	-	-	-	-	13	-		-	-	-	-	-	-	-	-	332	-	-	-	-	-	-	-	4	-	-	349	1.0
Finland	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	18	0.2
France	-	-	46	-	-	-	-	-		-	-	113	53	-	-	-	-	-	109	-	675	-	-	117	52	-	1165	1.8
Hungary	-	-	-	-	1	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	10	0.2
Ireland	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Italy	-	6	-	-	-	-	-	-	85	-	-		-	-	-	-	-	-	-	-	216	-	-	-	-	-	307	0.6
Luxembourg	-	-	37	-	-	-	-	-	10	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	47	3.6
Netherlands	-	-	- b/	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	191	-	-	191	1.3
Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	11	-	-	-	-	-	-	11	-
Poland	-	-	-	-	1	-	18	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	19	0.1
Portugal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Romania	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	26	0.4
Spain	-	-	-	-	-	-	-	-	310	-	-	-	-	-	-	-	1	-		-	-	-	-	-	-	-	311	1.8
Sweden	-	-	-	-	-	733	-	141	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	874	2.7
Switzerland	-	35	-	-	-	-	-	-	870	-	-	157	-	-	-	-	-	-	-	-		-	-	1748	-	-	2810	15.4
United Kingdom	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-		-	-	-	-	1	-
USSR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-		-	-	-	13	-
Western Germany	-	418	78 b/	-	-	-	-	-	10	-	-	-	-	114	-	-	-	-	-	-	818	-	-		128	-	1566	1.6
Saar	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	385		-	400	14.5
Yugoslavia	-	52	-	-	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		117	1.5
Imports (total)	-	545	161	26	125	733	19	141	1410 c/	369	1	350	72	139	-	379	1	-	109	330	1724 d/	-	-	4909	180	19	11742	1.4
Imports as % of national production	-	3.7	1.4	0.7	0.6	16.8	0.1	1.8	2.2	5.7	0.1	0.7	5.5	1.0	-	1.6	-	-	0.6	1.0	9.5	-	-	5.1	6.5	0.2	1.4	

Note: Importers' figures have been taken wherever possible, but where they were not available either the exporters' figures or estimates have been given. Since these two series of figures do not always agree the export total given in the table may differ from the export figures in national publications.

a/ Exchanges between adjacent countries only.

b/ Not including energy in transit to or from Switzerland.

c/ Including 25 x 10^6 kWh from the Republic of Andorra.

d/ Including 15 x 10^6 from Liechtenstein.

Table 8

Exports of Electric Energy in Relation to Production in Western Europe - 1937-1959(a)

Year	Total electric energy in 10^9 kWh		Exports as a percentage of total production
	Exported	Produced	
1	2	3	4
1937	2.3	145	1.6
1948	3.5	215	1.6
1949	3.1	230	1.3
1950	3.3	257	1.3
1951	4.2	287	1.5
1952	4.1	306	1.4
1953	4.7	323	1.5
1954	5.6	352	1.6
1955	6.5	383	1.7
1956	8.5	412	2.0
1957	9.2	440	2.1
1958	9.7	468	2.1
1959 P	11.4	498	2.3

(a) excluding Bulgaria, Czechoslovakia, Eastern Germany, Hungary Poland, Romania and the USSR.