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Evolution of the role of electric power in Europe (**)

Technical, social and economic factors affecting the electric power demand

The factors which at the same time determine and affect the electric power demand that will have to be met in the medium and long term in Europe may be classified in two different categories:

Factors encouraging the use of electric power, and in particular:

a) the expansion of the present use of electric power, and the new uses brought about by technological progress,

b) the savings resulting from the use of electric power in certain applications and cycles of industrial production,

c) the increasing use made by the population of electric power applications, due to the socio-economic progress,

d) the decreasing cost of electric power, as a result of better choices of primary sources, of increasing efficiency, and savings in generation, transmission and distribution, and in general in electric power management,

e) reduction in investments, i.e. capital cost, in particular as a consequence of scale economies,

f) the development of measures for the conservation of non-renewable energy sources — in particular of fossil fuels and above all of petroleum and its derivatives,

g) particular « flexibility » of electricity in the generation and utilization phases.

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(**) Conferenza tenuta a Montreal il 26 maggio 1982 alla International Conference on Electrotechnologies in Industries.

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As we shall see further on, in most cases an increase in the use of electric power helps the conservation of non-renewable sources. An interdependence clearly exists between the evolution of the cost of electric power and the development of its applications.

Factors limiting the use of electric power

a) The development of the actions, pursued increasingly since the Kippur War, for the reduction of the consumption of all energy sources, including of course electric power,

b) the development of the applications of alternative sources, thanks to the technological advances which made them more economical (for instance in the production of heat),

c) a tendency to relocate the manufacturing of energy-intensive products-those which require a high specific energy consumption (kWh/kg)—to the countries favored with a fairly abundant supply of untapped and particularly low-cost hydraulic sources, and

d) in connection with the preceding point, the possible adoption by the public powers in certain countries of a policy including among its main objectives that of the curtailment of electric power consumption through a gradual restructuring of industry, designed to substantially reduce the energy-intensive production (electrometallurgy, electrochemistry, etc.).

Further on, we shall analyse a few of the aforesaid factors that at the present state deserve a more careful examination.

THE COST PER KWH AND ITS DEPENDENCE ON THE CHOICE OF THE PRIMARY SOURCES USED FOR POWER GENERATION: THE SITUATION IN EUROPE

One factor that significantly affects the extent of the use of electric power is its cost, which favors certain important applications when it is relatively low, and penalizes them in the opposite case. Indeed, in certain applications a high cost of electric power is an inducement to seek to replace this form of energy with cheaper ones. This factor, however, has a much greater importance in the manufacturing of those products in which energy accounts for a substantial portion of the end cost. In such cases, a high cost of electric power can make it impossible for the industries to withstand international competition and makes them take unbearable losses, resulting sooner or later in the closing down of their factories.

These considerations lead us to stress the importance of the factors determining the production cost of electric power.

The factor by far most important from this viewpoint is the choice of the primary source from which electric power is generated. For this reason we shall focus our attention on certain recent estimates of the cost of the kWh, obtained

from sources which are not only available or accessible, but also accepted by the European countries, without going into details which would find no space in this report.

We shall consider here only the sources which can give a substantial contribution to the coverage of the demand for electric power through the end of this Century. These sources are fossil fuels—coal, petroleum, natural gas—and nuclear fuels—essentially uranium.

It is not to be expected that certain alternative sources can make, in the period considered, a significant contribution to the coverage of electric power requirements. To prevent misunderstandings, it should be made clear that this does not mean at all that the current efforts for the development of these sources—sun, wind, endogenous steam—should be slowed down: in fact, we are convinced that they should be stepped up. It would be absurd, however, to expect from such sources a significant contribution within the next twenty years.

To estimate the cost of the kWh we shall take as a reference year 1990, the same taken by certain national and international organisations. The comparison will be limited to coal, and nuclear fuels designed to feed the power plants equipped with light-water reactors.

Based on a survey conducted by the French Ministry of Industry beginning with 1981, and on the basis of the purchasing power of the currency at the same time, in 1990 the cost of a kWh in France from the various sources will amount to:

— nuclear kWh: 14 French cents

— kWh from coal: 25 French cents

— kWh from oil: 45 French cents.

Such detailed data are not available for all countries, but those shown above are fairly indicative with some minor adjustments. Certain estimates made by the Italian ministry of Industry are not very different from the French ones.

If then we take into account the need for keeping oil consumption as low as possible, because of both its high cost and the continuing uncertainty of its supplies, the choice narrows down to coal and nuclear fuels, and therefore a comparison of the cost of a kWh should refer mainly to the two production cycles using these two fuels as primary sources for electric power generation.

A study conducted in the countries of the European Economic Community has conclusively shown that electricity generation from the nuclear sources is clearly competitive.

Considering the nuclear power and thermal power plants under construction or planned, an estimate has been made of the average present worth cost (1), in January 1981 currency values, of a kWh generated in the two cycles. The results of the study have shown the average cost of a kWh from coal to be about 60%

(1) The present worth rate was taken to be 5%.

higher than that of a nuclear kWh, with the values for the individual countries ranging from 30% to 90%.

For the purposes of this report, a higher degree of accuracy would be unnecessary, as well as unattainable, to provide further support to the conclusion that, *in most European countries, the cheapest kWh is that from the nuclear source, since the kWh from coal costs more than one and a half as much, and the kWh from petroleum between twice and three times as much*. As indicated above, these percentages are given for the year 1990.

In relation to the foregoing, and with reference to the overall economy of each country concerned (this being justified by an efficient and generalised interconnection), the resulting cost of a kWh will be determined by the relative incidence of the primary sources mentioned above, to which we must add—where it is significant—the hydraulic source. Also, for a better coverage of the subject, consideration should be given to the economy and financial consequences of the aging of the plants, but on this occasion we shall not discuss this question.

We shall limit ourselves to give only a few meaningful data (Table 1) on the estimated 1990 share of each primary energy source in a number of countries.

These data suggest that there are appreciable differences in the electricity-cost structures of European countries.

It clearly appears that by 1990 some countries, such as France and Belgium, will hold positions of advantage.

The data contained in the table clearly reflect the consequences of the delays in the implementation of nuclear power plant construction programs in a few European countries. This is a subject which we have already discussed in a report submitted to the Plenary Session of the World Energy Conference held in 1980 in Munich [2], when we showed that electricity generated from the nuclear source is not only by far the cheapest, but also that which affords the best guarantees of service continuity, thanks to fuel supply security. In effect, for nuclear power plants there are practicallyy no problems as regards:

— access to uranium sources (for uranium, so to speak, there is no Middle East);

— fuel transport;

— the stockpiling of nuclear fuel. This operation is not particularly costly (and on the other hand the charge of one reactor core will last around one year).

It is no exaggeration to say that the degree of energy independence afforded by nuclear power generation comes close to that achieved with hydroelectric production.

This digression about the particular characters of the nuclear source finds its

(2) A. M. Angelino: *The cost of delays in building large electric power plants due to obstacles to their construction; the Italian situation*. Munich, 8-12 Sept. 1980, 11ème W.E.C.

TABLE 1 - *Percentual contribution of primary sources to power production in a few European countries in 1980 and 1990.*

Source of production	Italy		France		West Germany		United Kingdom		Belgium	
	1980	1990	1980	1990	1980	1990	1980	1990	1980	1990
Hydraulic (*)	28.1	17.9	28.4	16.0	5.2	4.0	1.9	1.5	1.6	1.4
Nuclear	1.2	11.5	23.5	70.0	11.9	36.0	12.1	18.2	23.4	50.6
Solid Fuels	9.5	31.4	27.4	11.0	59.2	50.0	73.5	69.8	30.2	31.1
Hydrocarbons	61.2	39.2	20.7	3.0	23.7	10.0	12.5	10.5	44.8	16.9
Total . . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: UNIPEDE.

(*) For Italy, including geothermal.

justification in the fact that the assurance of continuity in electric power supply is of primary importance for all of its applications.

In any event, the subject matter of this chapter will form the basis for certain conclusions which we will reach in discussing the development of industrial applications.

The intrinsic characteristics of electric power which encourage its use

We shall start with some brief considerations of a general nature tending to emphasize the particular "flexibility" of electric power, in both the generation and the utilization phases.

Among the various usable forms of energy, electric power distinguishes itself mainly for certain characteristics which are lacking in other secondary sources.

a) In most cases, electric power can be economically generated from all industrially usable primary energy sources and can be converted, again economically, into all usable forms of energy.

b) Electric power can be generated in high-capacity plants, transmitted economically and in quantities variable to suit the requirement, up to some million kW for each line and to distances as great as 1000 or 2000 km and greater, and finally distributed to users within a wide range of densities over a territory which reaches and exceeds, without technical difficulties, the national limits. Transmission losses over long distances, as well as distribution losses, are moderate and economically acceptable.

c) In the utilization stage, the conversion into all other forms of energy involves losses and costs which are generally quite limited.

d) In its applications, electric power not only creates no environmental problem, but actually makes it possible to solve several of them, sometimes quite serious.

e) As regards the producer-user relationship, what is involved is not a "supply" in the true meaning of this word, but rather the rendering of a "service". The producer makes available to the user the capacity contracted for, but is the user and the user alone who has the right to freely choose at any time how much capacity he requires, without the supplier having anything to say about it. This is a relationship quite unlike the one existing between the suppliers and purchasers of coal, oil, etc.

f) In many applications, electric power is the only possible form of usable energy. We shall come back again to this point when discussing the regulation and remote control systems, most automatic systems, etc. Some industrial processes and some advanced technologies would not have been feasible without electric power.

The characteristics of electricity listed above, and several others, are summed up in the expression "flexibility of electric power" which we have used. It is to this flexibility that we can attribute a great many of the developments in the uses of this form of energy.

Electric power savings

We have stressed on several occasions that this is an actual "virtual source" which ranks first in the order of priority for the management of the uses of the various energy sources in general, and of electricity in particular. As regards the latter, one fact should first be recognized: electric power (a high-grade form of energy) has long since been used quite efficiently. Conservation measures — by eliminating wastage and unnecessary uses and promoting an even more efficient utilization — can make a contribution to the reduction of requirements which, while significant in absolute terms, will be relatively small in percental terms. This saving, in the medium term, may amount to 10% of the electric power requirements.

In the second place, the potential energy conservation areas should be distinguished, by their different characteristics, into two groups: the first will comprise the production-distribution process, i.e. the phases of electric power generation, transmission and distribution to the users. The second will comprise the end uses, therefore including both the conversion made by the many users of electric power into useful energy (motive power, heat, chemical energy, etc.) and the action obtained from the useful energy (performance of an operation, compensation of heat losses to maintain predetermined temperature conditions, conversion of the chemical state of certain substances, etc.).

The first group presents narrow margins for energy savings: in effect the electric power production-distribution process has already availed itself of nearly the fullest benefit of all possible economies of scale and mass and in general of the technical-economic optimization: in optimization evaluations, energy losses and less-than-efficient uses translate themselves into production losses and are eliminated or contained to the lowest levels consistent with the use of other resources. A vast electric power system, territorially integrated by interconnection, such as for instance the Italian system, also makes the continuous advance of technical-economic optimization possible through the adjustment of the generation and transmission system to the conditions of best efficiency as they vary in time.

In this field, more noteworthy results are brought about by the development of automatic dispatching systems which have achieved a high degree of efficiency and are based on an integrated operation of the production and transmission system to achieve the highest degree of economy and reliability.

In the area of the production-distribution system, the research and development activity holds hope for higher efficiency levels, which may be achieved through a better utilization of the capacity available in low demand hours, the

utilization of the heat discharged from the turbines, the establishment of new technologies. As regards the latter, there is special interest in the development of nuclear power stations equipped with breeder reactors, which are now in a rather advanced development stage. As it is known, by far the best feature of these reactors is their capacity to multiply the energy yield of the prime nuclear source by a factor of 50 to 70 as compared with the current reactors. Not to be underestimated, however, also because of its positive consequences on the environment, is the fact that the efficiency of conversion from thermal fission energy into electrical energy is in the order of 40% for breeder-reactor plants, as compared to 33-34% in the present nuclear plants.

Of considerable significance are the electric power savings that can be made in end uses in large, medium and small industries, as well as in household and other uses.

In the industrial sectors, apart from certain energy-intensive productions (aluminum, magnesium, etc.), the fact that the incidence of the cost of electricity is very low results in an inadequate concern about the need to make a more rational and efficient use of electric power.

In the field of *electric traction*, the use of static converters (chopper and inverter) has made possible substantial electric power economies during the starting and the stopping phase of trains. Such improvements have a great importance in the urban and suburban lines where startings and stoppings are very frequent. Several European countries have recently adopted for such lines minicomputers on board of the locomotives so as to minimize electric power consumption in the frequent starts and stops. In the most favourable cases all these provisions led to a saving of 40% in electric power.

In the *household sector*, beside the wastage and unnecessary uses whose elimination depends on an extensive program of user information and education which has long been conducted in Italy, technical possibilities exist for energy savings, for instance by building better appliances and indicating their energy consumption to the users, to prevent the latter from being induced to save on the cost of the appliances and accepting unknowingly an operating cost quite heavier in the overall economy.

In conclusion, it is worth mention that, as regards savings in end uses in Italy, ENEL — from the beginning of its activity in 1963 — has carried out and is continuing an intensive and extensive program of information, technical assistance and even specific consulting services.

The replacement of electricity with alternative renewable energy sources

In this area, the most significant development, specifically in the household sector, is that of the use of solar energy for home *water heating*. The contribution of solar energy, and therefore the corresponding reduction in the consumption of electricity, can reach and even exceed 50% of this sector's requirement.

The use of solar energy is in a developing stage. Progress is very likely to be rapid. In Italy, for instance, the production of solar panels has risen from 15,000 square meters in 1977 to nearly 50,000 square meters in 1980.

We take this opportunity to call attention to the possibilities offered by solar energy in space heating and conditioning: the contribution of this sources, within 10 or 15 years, may well reach significant amounts in certain countries, especially in Southern Europe.

These considerations also apply to agricultural uses, for which the use of wind energy is also developing. The evolution of these rural applications of sun and wind energy is hard to predict; from the quantitative viewpoint, however, the incidence of these sources can only be modest.

The *sector of electric transportation* is not interested in the development of alternative power sources.

The future prospect of the applications of electric power

The applications are so varied and many that it would be impossible here even to list them one by one. We will therefore have to divide them by groups and to make some considerations about each group, in order to obtain some indications concerning the rise in the demand for electric power in the medium and long term.

Household Applications

For the near and even more so in the medium and long term, we expect in this group some interesting innovations, which concern mainly the applications of informatics; these uses involve but limited power requirements, in spite of their major social impact on the organization of the activities in industry and trade, in office work and even on family life etc.

The applications whose technology is already established will have a growth linked with economic and social development, and above all with the standards of living of the populations.

Among the home applications of electricity there are some to which we shall turn our attention, because of their likely developments in Europe.

Building Air Conditioning

This application is not yet widespread enough in Europe, and especially in Southern countries, such as Greece, Spain, Italy (particularly Southern Italy) and we most therefore expect, already in the medium term, a rather sizeable growth of this class of equipment, whose technology is now fully established.

Heat Pumps

In the new buildings, particularly those intended for offices, hotels, industrial and business activities, air conditioning is obtained with centralised systems.

The essential element in such systems is the heat pump, which in the summer operates to transfer heat from the inside of the buildings to the outdoor, the opposite operation being performed in the winter.

We shall refer here to the heat pump designed for winter heating only, and occasionally also for the summer conditioning of individual spaces or apartments. This is, so to speak, a decentralized application of the heat pump.

As compared to the United States and Japan, this kind of equipment is still used in Europe on a relatively modest scale; however, in 1980 some 100,000 heat pumps were installed in Europe in residential and business premises, and it is expected that their number will rise to two million units by 1990 (*). On the other hand, heat pumps are more widely used in the North than in the South of Europe.

Although the problem of the economics of individual heat pumps still creates some perplexities, mainly because of their high installation cost, we do believe that their applications will grow in the medium term. This will involve a rise in the demand for electricity, but will make it possible to achieve at the same time two results: to reduce pollution in the cities (from this viewpoint, the heat pump is completely clean and replaces in heating all that would be done by burning gas oil, which produces pollution effluents), while at the same time contributing to the conservation of non-renewable energies.

In effect, the energy content of the fuel needed to generate at the power plant the electricity needed to power the heat pumps is less than that required to feed a conventional oil-burning boiler heating the same apartment. Furthermore, in the coming years the percentage of electricity from the nuclear source will be steadily rising, and the use of the electrically powered heat-pumps will help save fossil fuels, in particular oil.

Electricity consumption resulting from an extensive use of heat pumps may be substantial, but it is now hard to make predictions. Some estimates, however, suggest that by 1990 the peak power demand resulting from the use of heat pumps (2 million units as indicated above) will amount to around 10,000 MW.

In some countries where electricity generation from the nuclear sources is growing rapidly and may meet, together with hydraulic sources, almost all of the electricity requirements predictable for the next 10 to 15 years, consideration should be given to the use of electricity for heating purposes, using resistances to convert electricity into heat. In these cases, users are very often encouraged, through special rates tarifs, to draw insofar as possible power in the "empty hours" of the load diagram. This requires equipment fitted with means of storage

(*) The State of Development and Commercialization of the Compressor Heat Pump in Europe, by P. V. Gilli, F. Schabkar - Graz University of Technology.

which can store heat mainly at night and return it when the spaces are to be heated.

This heating system too will appear the more advantageous, the greater the nuclear contribution to electric power generation will be.

A comparison between resistance and heat-pump space heating would be interesting, but it falls outside the scope of this paper.

Transportation

In the field of transportation, the application which consumes a substantial amount of electric power is the electric traction on urban, suburban and above all interurban railways.

In the European Community "of the nine" in 1979 the consumption in this sector was 27 billions of kWh representing 2,2% of the total consumption in the Community 1210 billions of kWh) and 68% of the total need of energy kind for railways.

The increase in this consumption depends on:

— the growth of railway electrification, in Europe this growth will be relatively limited in countries such as Italy, Switzerland, Holland and Sweden where the not electrified lines whose electrification is economically justified are quite few, whereas it will be greater in countries such as France, Federal German Republic and Great Britain where the not electrified lines are quite numerous;

— the intensification of traffic on the existing lines, and

— the increase in the speed of trains — above all, passenger trains — which, all other factors being equal, involves large power consumption.

In the field of *road transport*, the development prospects of electric cars deserve special attention because of the great impact of the many changes brought about by the use of these vehicles. An extensive introduction of electric cars, however, depends on the success of the research now in progress in a number of countries towards the development of a practical and economical storage device of satisfactory performance and considerably lighter than the existing ones.

Significant efforts are being made towards this goal, with many researchers working in many and advanced laboratories throughout the world, and with substantial funds allocated, mainly by private industry.

This reflects confidence in the results expected, but it is impossible to predict when electric cars will be ready for mass production and to replace the cars to a large extent powered by internal combustion engines.

It is unnecessary to comment on the tremendous importance that these results will have on electricity consumption in future years.

Another factor — which concerns, however, all means of transportation, land, air and, very marginally, maritime — is the meeting of the power requirements of the equipment for control, safety, remote operation and signaling systems, which have recently made substantial progress and will continue to do so in the future.

The power consumption of this equipment is very limited, but electricity is practically their only power source.

Agriculture

Electric power consumption in the farms has been steadily growing, especially after World War II. In Italy, the average annual consumption growth rate, in the 1970-80 period, amounted to 8.9%. This growth was substantial also in the broader area of the Community of the Nine: 7.4% a year from 1960 to 1974 and 3.9% from 1974 to 1980. This slowing down was largely due to the oil crisis, which has pushed up also the prices of electricity, but we believe that there can be no doubt the future development of rural electrification, and about the fact that the rate of growth may increase even in the near future.

Industry

Industry is the biggest single electric power consumer, taking up about half the total in European countries (48% in 1980). For this reason, and others discussed further on, industry will be given our close attention, aimed at the same time at the factors acting in both directions: to boost and contain electric power consumption.

In dealing with the *electricity consumption trends in industry* we have to consider that in industry, much more than in the other user categories, electricity consumptions depend on the price, and thus on the cost of electric power; it is mainly for this reason that earlier in this report we discussed the cost of electricity.

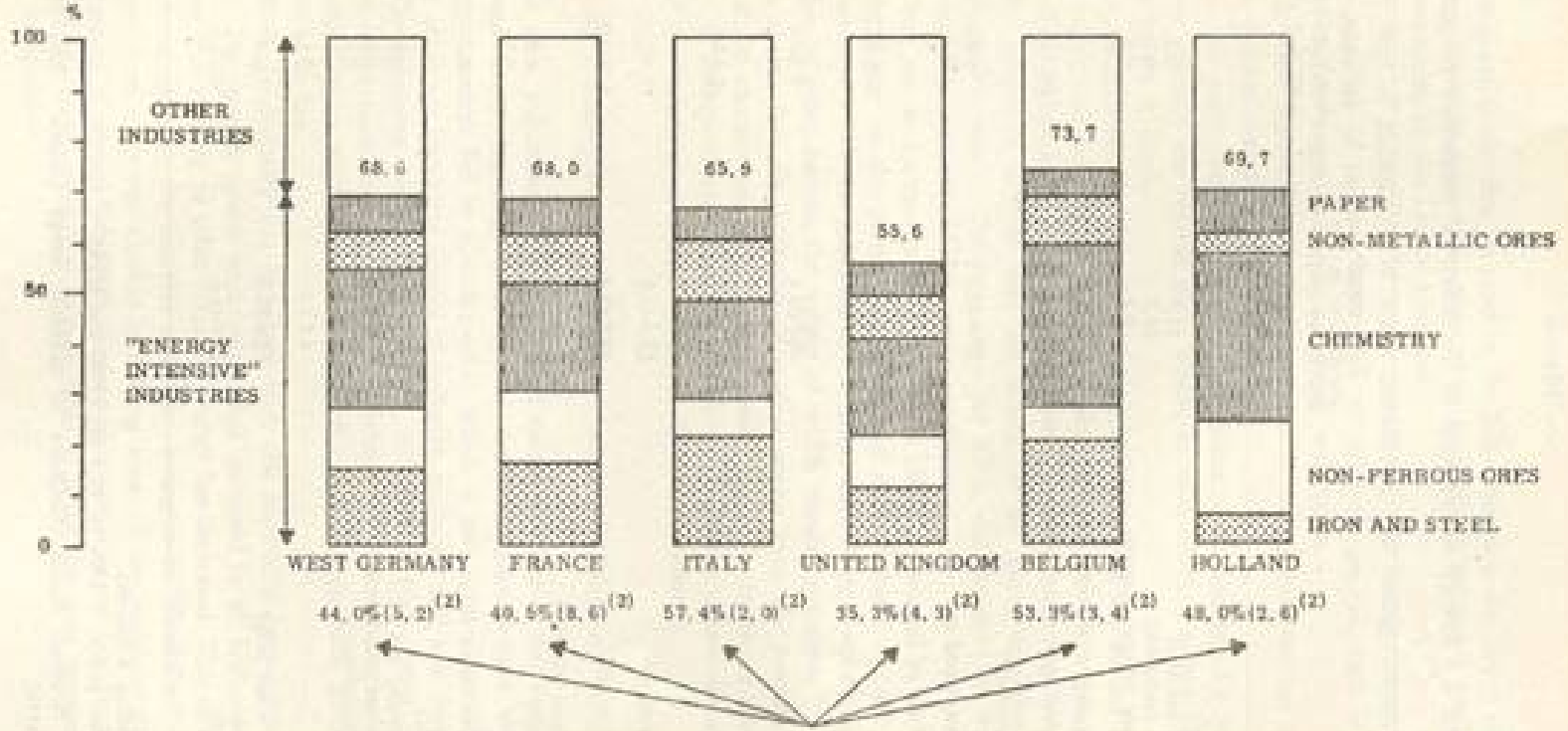
We shall deal here first of all with that special group of industry in which electricity consumption accounts for a high percentage of the cost of the end product and then with the "non energy intensive" industry.

Electricity consumption in "energy intensive" industries

This priority — in view of the subject of this paper — is justified by the fact that, in 1980, in the energy-intensive industries, electric power consumption accounted for 69% of the total industrial consumption in West Germany, 68% in France, 66% in Italy, 56% in the United Kingdom, 74% in Belgium and 70% in the Netherlands. For these countries fig. 1 shows not only the data mentioned above, but also the percentage incidence of the industrial consumption versus the national consumption of electricity and the consumption of the energy sector (*).

(*) The energy sector consumption includes that of the energy-producing industries. Some of the electric industry consumptions, that is, those for power generating plants and pumped-storage stations, as well as the transmission and distribution losses, have not been taken into account.

Fig. 1 - Contribution of energy-intensive industries to electric power consumption for industrial uses (1980).



(1) Excluding Energy Sector.
(2) Percentage of Energy-Sector Consumption of the Total Electric-Power Consumption.
Ref.: Eurostat - Bulletin Mensuel d'Energie Electrique - 12/1981.

TABLE 2 - *Energy consumption in the industrial production process.*

	Total energy consumption in the production process (MJ/kg) (1)	Of which: electric power (kWh/kg) (2)
Steel (Liquid)		
— from ore (furnace)	11.7	0.2
— from ore (reduction)	20.2	0.7
— from scraps (electric furnace)	5.2	0.5
Aluminium (raw)		
— from aluminium	150.0-196.4	14.3-18.7
Copper (Electrolytic)		
— from ore	22.9-86.7	1.0-5.0
— from concentrated ore		0.3
Magnesium		
— from ore	290.8-381.8	22.0-16.7
Zinc		
— from ore	48.9-66.4	0.3-0.4
Lead		
— from ore	22.7-45.3	0.9-0.6
Tin		
— concentrated ore	13.4-41.8	1.3-0
Ethylene (from oil)	38.6-68.4	0.05-0.06
Polythene (from ethylene)		
— high density	9.7	0.7
— low density	90.7	0.8
Sulphuric Acid (from SO_3)	1.8	0.2
Vinyl Chloride		
— from acetylene and HCl	4.5	0.07
— from ethylene and chlorine	29.3	2.0
— from dichlorethane	479.3	2.3
Cement	4.8-7.1	0.1
Paper (from wood pulp)	12.6-26.3	0.4
Glass (bottles)	14.0-16.6	0.2-0.3

(1) Including Feedstocks.
(2) Electric power: 1 kWh = 10.5 MJ (2500 kcal/kWh).

Source: Boustead, Hancock-Handbook of industrial energy analysis - Ellis Horwood Publishers (1978).

We can therefore say that, in most of the EEC countries, the power consumption by energy-intensive industries comes close to 70% of industry's total, with the single exception of the United Kingdom.

By way of example, it is worth mentioning that energy-intensive products include materials of primary importance of industrial growth, such as steel, aluminum, copper, magnesium, vinyl chloride and others.

For these materials table 2 gives the total energy consumption of the production process and the electricity share.

At this point, we could tackle the problem of determining for each energy-intensive industry the highest price which, in each country, it can bear for the electric power it needs.

An analysis of this kind would be rather difficult if we wanted to get estimates having a degree of precision unattainable in this sector; however, conclusions that can be regarded as reliable, can be drawn from our preceding discussions.

We believe it evident that the future of the energy-intensive industries depends on the trend in the power cost per kWh, and therefore on the choice of the primary sources utilised for power generation.

There are no doubts that the price of the electricity needed by such industries depends in part on the particular condition of each of them, but the differences in power cost which we indicated in the initial part of this paper can in no case be offset by other factors, the weight of which remains marginal.

It ensues that *the exclusion of nuclear power from the primary sources to be used for electric power generation would inevitably require a change in the policies of energy-intensive industries, which in most cases constitute a substantial part of the industrial structure of several European countries.*

Electricity Consumption in "Non Energy Intensive" Industries

In these industries electricity is used mainly to improve the work conditions and productivity. Lighting, motive power and information science are the most important services fed by electric power, which is also the indispensable form of energy to obtain important results in pollution reduction and heat recovery.

The foregoing explains why after the oil crisis in 1973 power consumption in this sector increased; the possibilities offered by the information science and its application to work automatization and rationalization have given a further impulse to its use.

Work productivity has increased with the electricity consumption per employee. The specific power consumption has increased in all European countries, whereas that relating to other forms of energy has decreased. This different behaviour is explained by the fact that electricity, owing to its "flexibility", is generally the only form of power capable of solving some of the problems posed by the development of several industrial processes that aim at improving the products and reducing the costs, conditions indispensable to stand the ever increasing international competition.

The multiplicity and variety of the non energy intensive productions do not allow here a detailed analysis of the matter. However, it is obvious that the industries where power consumption has a marginal importance are not conditioned by its cost; thus, a more exhaustive analysis of the matter would not modify our conclusions.

The prospective evolution of the role of electric power in the growth of European industry

One of the most important, or possibly the most important, conclusions drawn from the facts outlined above can be summarized as follows:

— in all advanced countries industry is by far the biggest electric power consumer;

— the incidence of the industries whose products are characterized by a high specific electricity consumption, which in turn determines the international competitiveness of those products, generally exceeds 60% and even 70% of the total industrial power consumption;

— it follows that in each country the cost of electricity is a decisive factor for the very existence of such industries, and the cost of electricity essentially depends, to the degree indicated above, on the choice of the primary sources used, and above all on the contribution of nuclear power; this choice will decisively affect those industries' chances of survival.

At this point one comment might not be unnecessary: we have not considered the possibility that steps be taken to let energy-intensive industries retain an apparent economy viability through the adoption, in one form or another, of a "political price" of electricity through decisions by the public power. This would result in the taxpayers bearing the losses of such industries, a situation which we consider inadmissible.

Apart from this comment, the foregoing considerations lead us to the conclusion that the forecasting of electric power requirements in each European country largely depends on the choice of the primary energy source, considering the alternative of fossil fuels or uranium.

Since it takes ten years from the decision to build a power plant to its commissioning, the decisions adopted now will not make their effect felt prior to the end of the decade. In the meantime, unfortunately, the situation cannot be changed.

It is in view of this situation, the negative consequences of which we have stressed in our report to the 11th World Energy Conference, held in Munich, that in the course of the latter's Plenary Session in 1980 a Round Table was held to consider the possibility of reducing nuclear power plant construction delays.

A FEW COMMENTS ABOUT POWER REQUIREMENT PROJECTIONS

It seems appropriate, at this point, to call attention to the estimates of future electric power requirements.

In the decades that followed the birth of the electric power industry, the consumption of electricity in industrialized countries has been following, with relatively modest and temporary deviations, the law of "doubling every ten years".

At the same time, the rise in electricity consumption has been following closely the pattern of the growth of the *gross national product*, in almost all industrialized countries.

In the evolution of the electricity consumption with respect to the above mentioned empirical law and in that of the gross national product, fairly large deviations have taken place during World War I, the Great Depression of 1929-32 and World War II, but the corresponding deviations in the electricity consumption curve though relevant, were temporary and the departures from the trend line, very close to exponential, were followed in a few years' time by a return to the average values.

With particular reference to the second criterion, we cannot look back in this report at the reasons for the match between energy consumption and GNP evolutions, but it does seem appropriate to call attention to the reasons why the consequences of the oil crisis may cause changes of major importance and long duration — if not permanent — in the evolution of electric power consumption relative to the past trend. This rules out, in any case, the possibility of basing the electric power requirement forecasts made with the "synthetic method" on certain criteria followed in the past, which over various decades have indeed found confirmation in reality.

First of all, a general consideration: this criterion is justified in the case in which the industrial structure does not undergo significant changes as regards in particular the incidence of energy-intensive industries, because of the reasons stated in the foregoing.

As regards the uses of electricity in the other industries and in the different sectors, the soaring of the costs of fossil primary sources, especially petroleum, has induced energy price rises which have given more and more impetus to the measures designed to achieve the greatest economy in the use of electricity and to replace it with other energy sources having a lower specific incidence.

On the other hand, this situation discourages the plans for the establishment of new energy-intensive industries, also in view of the fact that most of them (see for example electrometallurgy and electrochemistry) are now in a state of crisis.

There is another factor, however, which can play a significant role in future years: the possibility of producing electric energy intensive items in those countries still possessing untapped hydroelectric resources, the utilisation of which would be very economical.

These resources are located mainly in some developing countries and are

very substantial, adding up in the whole to a generating capacity of some thousands of billions of kWh a year.

We have had an opportunity to discuss this question at the Plenary Session of the World Energy Conference held in Detroit in 1974, and to take it up again at the UN Conference on "New and Renewable Energy Sources" held in Nairobi in August last year.

We believe that these considerations are sufficient to show that, in making electricity requirement forecasts for the European countries, we cannot take as a basis estimates arrived at through synthetic criteria which proved reliable in the past, but must take into account certain factors which, by their very nature, are highly uncertain.

We believe we have called attention to the most important of these factors. On the other hand, it results from the foregoing that the most effective way to reduce the uncertainty about the future is that of taking all measures designed to reduce gradually, but as fast as possible, the cost of electric power by choosing the primary source that is most economical and affords the greatest assurance of independence in the terms mentioned above. France, Belgium and some other European countries are pursuing programs which afford the fullest guarantee from this viewpoint.

The situation of countries with long-delayed power plant construction programs

There are other countries, however — and Italy is unfortunately one of them — in which the stubborn opposition of public opinion and local authorities has caused delays in the construction of new thermal power plants, and especially nuclear ones. These delays could create a shortage of electricity if the current crisis of the big industries could be overcome in the future years as we hope.

In such a state of necessity, for those countries where the generation of electric power involves large consumptions of imported fossil fuels, in particular oil, the following problem arises.

At least for certain products, apart from any economic and industrial consideration, we can ask ourselves — taking into account supply security and dependence on the imports of certain essential raw materials — whether it is preferable to import a finished product, or instead the oil required to obtain the electric power needed to make that product.

Conclusions

The nature of the subject of this paper is such that it would be impossible to sum it up in a few words. By way of conclusion, however, we can single out some of its salient points.

To determine the role of electricity in Europe's economic and social development it is necessary to consider separately two major fields of use of this form of energy, whose particular characteristic is "flexibility".

a) The sectors in which the cost of electricity is a relatively small component of the value of the service rendered to the user or of the product for the making of which electricity is used, and

b) the other sectors, in which the cost of electricity accounts for a significant portion of the value of the product or service produced with that electricity.

The sectors in Group *a*) considering the great advances in technology, do not pose for the future substantially new problems from the standpoint of the evolution of the role of electricity in its innumerable uses.

Those in Group *b*) raise important problems, because the chances of survival of some industries operating in a competitive situation depend on the cost of electric power, and because this cost depends largely on the primary source used to generate that power.

It ensues that, in the countries concerned, any decision about this choice will have a decisive bearing on the development prospects of the industries referred to above.

Another consequence is the uncertainty which, things being as they are, plagues the energy requirement forecaster. These requirements are indirectly connected with the alternating choices between fossil fuels and nuclear fuels, which cause the delays, often wholly unpredictable, in the implementation of electric power plant construction programs.

From this point of view, the situation in the various European countries shows considerable differences, due to the effects of the opposition to the construction of plants.