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METHODS OF FORECASTING DEMAND FOR ELECTRICITY

Working Group 03 of Study Committee 37
(Power System Planning and Development)

Convener : D. Fouquet (France)

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FOREWORD

Recognizing the crucial role of electricity demand forecasts as an hypothesis for network planning, the Study Commitee 37 set up a working group (37.03) on this subject. The working group has already produced a paper (*) on the role of demand forecasting - stressing more particularly its role in decision making and its link with energy policy - and a detailed study of the factors affecting the evolution of electricity consumption in industry (**).

At this stage, the group felt it necessary to undertake a general survey of methods actually used to forecast electricity demand, in terms of energy consumption or in terms of load. The objectives of this work are (1) to inform member countries on the methodological advances achieved in other countries, and (2) to give a general framework to further activity of the working group, in stressing the topics on which more detailed investigations would be most valuable.

INTRODUCTION

The concept of electricity demand forecasting covers in fact a number of diverse activities, corresponding to different purposes. Forecasts may concern either the short term - for budget or actual management purposes - or the long term, to support investment planning. They can be done at National, Regional or local levels, being then particularly useful respectively for planning of generation capacities, of the transmission and interconnection network, and of distribution networks. They can also concern energy demand, peak demand, or the whole load curve.

We focus here on long term (10 to 20 years ahead) forecasting of both energy and load. This report is based on contributions made by 10 countries : Australia, Belgium, FRG, France, Italy, Japan, Netherlands, Sweden, UK and USA.

1. THE INCREASING IMPORTANCE OF ELECTRICITY DEMAND FORECAST

During the 1950s and 1960s, interest in demand forecasts was limited. The high and steady growth rate of demand lead many to think that simple extrapolation methods were largely sufficient for planning purposes. In addition, the consequences of forecast errors were limited : overestimates of future energy demand were quickly made right by demand growth, and the temporary excess capacity resulting of such errors were soon absorbed ; underestimates were not critical either, because turbine generators fired by cheap oil or gas could plug the gap while new baseload plants were coming on line.

This easy context began to change in the late 1960s, when it became progressively clear that the post war rapid economic growth period was coming to an end. Uncertainty about future growth increased, as is attested by the first report of the club of Rome on "Zero growth". It became clear that electricity demand growth was dependant on explanatory factors like the rate of growth of the different sectors of economic activity or the accelerated evolution of social structures and behaviours, and that global extrapolation methods were not sufficient to take into account these factors.

The 1973-1974 oil crises increased sharply the concern about an improvement of electricity demand forecasting. The uncertainty on future energy prices and on the response of the economic actors to this new and possibly evolving price structure was now added to more uncertainty on economic growth. At the same time, the consequences of forecast errors became much more important than previously. In a low growth economic context excess capacities may last several years, turning it into a financial burden for the utility. Underestimates may be even worse since it takes at least 8 years to license and build a coal-fired or nuclear plant, and that low cost short term answers are no longer available.

The beginning of the 1970s has also been characterized by the development of the public concern (and thus also the concern of various political groups and administrativ structures) in environmental issues. Thus, decisions on the construction of generating plants, and as a consequence the demand forecasts on which those decisions were based, were no longer "private" issues for utilities, but more or less political issues. It was then necessary not only to forecast, but also to explain the forecast. This led to the necessity of more detailed methods, making more clear the hypothesis and results, and the fact that even in the framework of voluntary energy conservation policies a growth of electricity demand, and thus the necessity of new generating plants, was likely to arise.

In response to this growing importance of electrical energy demand forecasts, the methods used have evolved rapidly during the last twenty years, and still continue to improve through important methodological work.

But at the same time that more accurate and explicit forecasts were necessary, the fact that these forecasts were uncertain, particularly because they could only be conditional forecasts based on uncertain hypotheses, became more and more evident. In most countries, this led to the use of several scenarios instead of a unique forecast. These scenarios can take into account various hypotheses on "classical" explanatory variables - as growth rates in various economic sectors - but also follow a more prospective approach, and throw light on the consequences of more radical changes, discontinuities, or new factors, including those not easily quantifiable (e.g. consumer attitudes, government policies, institutionnal or regulatory framework, emerging new technologies, etc...) . However the way in which this multiplicity of scenarios is taken into account in actual decision making remains a difficult issue.

Last, but not the least, demand forecasts are no longer only a question of methodology, but also a subject of negotiation between several social or economic actors, who may have divergent interests and opinions on the more likely, or more desirable, growth of electricity demand. This last aspect, developed in more detail in §4, helps to better catch the actual scope of forecasting methodology.

2. THE TREND TO MORE DETAILED APPROACHES FOR ENERGY FORECASTS

We have already explained why more detailed and explicit approaches became more and more necessary during the last two decades. In some countries, this improvement in forecasting methodologies was already

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(*) "The conceptual and practical problems underlying demand forecasting for electric energy" - Published in Electra.n° 103

(**) Presented at the 1986 meeting of the S.C. 37, (Paris,September the 2nd), and submitted for publication in Electra.

undertaken at the end of the 1960 s. This was actually the case for some U.S. utilities, in Sweden, in the U.K. or in France. But this trend generalized to all countries under review after the first oil shock.

The methodological ways used, as well as the rapidity in the actual modifications of the methods, varies from one country to the other. This depends of course of the divergent characteristics of these countries, on social, economic, energy, administrative, political... points of view. But it depends also sharply on the availability of data on which to base those forecasting models.

2.1. The main methodological approaches

Eliminating purely statistical approaches, the use of which is limited to short or medium term forecasts, we can distinguish four main approaches, which are not entirely exclusive from each other, thus leaving room for a fifth approach of various "mixed" methods, which tends now to be the most in favour in a majority of the countries under study.

It must also be noted at this stage that it is frequently observed that there is not a unique method used, but several methods leading to a "trade-off" between their results, or to the use, in addition to a main method, of alternativ approaches for checking purposes.

2.1.1 - The econometric approach

In the econometric approaches, the main focus is on the links between electricity consumption and explanatory variables such as economic growth (or growth rates in several economic sectors), number of households, income, fuel prices, and so on...This approach can be used at different levels : at a global level, thus trying to explain directly total consumption, or in a more realistic way at the level of broad economic sectors as industry (with in some cases a further breakdown in several subsectors), commercial and domestic sectors. This approach will also be found as part of mixed methods (see (e) below), particularly in the modeling of industrial consumption.

Aggregate data for a recent historical period is then assembled and the parameters of the equations estimated using standard regression techniques. For forecasting purposes, the equations are evaluated using projected values of the independant variables and the estimated coefficients from the regression. Functional form of the equation varies from simple linear to single -equation log- linear with Koyck lag, to complex system of demand equation resulting from formal models of producer cost minimization.

The main advantage of this approach is to make clear the link between electricity consumption and explanatory variables as GNP or fuel prices. It is then particularly well fitted to answer "what if" questions

2.1.2 - The "end -use" approach

Engineering end-use models follow the intuitive notion that energy is used only as an intermediate means of obtaining a desired service : heat, light, power... The focus is on the physical stock of energy-using equipment, for example, the projected number of electric dishwashers in homes. Thus they typically begin with the accounting identity that total energy consumption equals the sum of the energy consumed for each end-use category (e.g. space heat, air conditioning, machine drive...), which in turn can be represented by the product of terms for : (1) the number of devices in each category, (2)a measure of the energy-using capacity of the device, and (3) a measure of the average rate of utilization of the device. In equation form :

$$E = S \times N \times P \times H$$

where :

E = energy consumption of the appliance in kWh
S = saturation in number of such appliances per customer
N = number of customers
P = power required by the appliance in kW
H = hours of appliance use

In a number of cases this equation takes a slightly simplified form, i.e. :

$$E = S \times N \times C$$

Where C is the average consumption of the concerned device, the projection of which takes implicitely into account modification in the average rate of utilization of the device. In the case of space or water heating, or of air-conditionning, C may also be written as :

$$UC \times Q$$

with :

UC = annual consumption per square meter (or per cubic meter of hot water)
Q = number of square meters per home (or number of cubic meters per home)

These end-use approaches are very often used for the domestic sector, and,when the necessary data are available, for the commercial sector. They are more difficult to put into practice for industry, where the large number of end-uses is an important obstacle.

Because of their technology emphasis, such models are especially well suited to looking at the impact of improved technology on energy consumption. But a straightforward engineering approach that focuses only on physical factors can miss the emergence of new end uses, as well as other important effects, such as the impact of rising energy prices as a stimulus to energy efficiency. Furthermore, to be used in forecasting applications, projections must be made of future values of each of the factors in the equation. This requires projecting market penetrations of various devices, while accounting for fuel substitution, average capacity and efficiency factors in the future, as well as average utilization rates.

2.1.3. - Multi-energy approaches

Besides models devoted to the forecast of demand for electrical energy, have been developed models dealing simultaneously with final demand for the various kinds of fuels, i.e. not only electrical energy, but also coal, natural gas and several oil products (light or heavy fuel oil, etc...). They may use econometric, end-use or mixed approaches. This kind of models frequently distinguish specific uses of fuels from uses where the different kinds of fuels are competing.

This multi-energy model allows a satisfactory approach to the important inter-fuel substitutions which have taken place since the first oil shock, and which will continue to play a noticeable role in foreseeable modifications in the fuel mix. Even if the final aim is only forecasting the demand for electrical energy, such models can be very helpful. It is clear, for instance, that substitution from oil to electricity in a given sector will not depend only on the relative prices of these fuels, but also of the level of oil products consumption in this sector : modeling the decrease of this last variable may thus be necessary to forecast demand for electrical energy.

Such models have been developed in some countries , like The Netherlands (energy forecasts of the Central Planning Board) , Sweden (forecasts made at the national level) or France (EDF's forecasting models - cf. § 2.3)

2.1.4 - Models merging macroeconomics and energy representations

An alternative way to forecast energy demand consists of developing in more detail the representation of energy flows in a macroeconomic model, or of linking a macroeconomic model to an energy model. These approaches are frequently used (for instance in USA, France, or the Netherlands), but mainly by the administration, economic forecasting centers - either private or linked to universities - or by administrativ bodies responsible for economic planning, rather than by the utilities themselves.

Such models allow one to take into account the feedback of energy related variables on macroeconomic variables. But often (with some exceptions) they deal only with an aggregated representation of energy flows, which may be insufficient for power sector planning purposes.

2.1.5 - Mixed econometric/end-uses approaches

In recent years, a number of factors have led to simultaneous uses or to a merging of econometric approaches and end-uses approaches.

Econometric approaches may be more adequate for some sectors (industry), and end-use approaches for others (domestic sector). In the case of the commercial sector, the method used depends mainly on the availability of detailed statistical information.

In some cases, econometric approaches (or even several econometric approaches) may be used as checks of end-use approaches, or to answer "what if" questions. This aspect is quoted particularly by Japan (for industrial, commercial and residential sectors) by FRG (for industry, transport, small consumption and residential sectors) or France (for specific uses in the domestic sector).

An actual integration of both approaches (for one or several sectors) is also an observed trend. This can be explained by several reasons :

- Future levels of market penetration or utilization rates for each end use will be strongly affected by consumer response to various important economic factors : econometric analysis of historical data is one important source of information on the likely impact of these factors. This leads to an integration of econometric relationships in end-use modeling framework. The US model REEPS (Residential End-use Energy Planning Model) is a good example of such an integration.

- There is a growing need (e.g. in Sweden, in France or in the US) to take explicitely into account in the forecast the results of the policies followed by utilities (or by administrative structures, energy conservation agencies...) to influence future load (for instance : strategic conservation, load management, market penetration policies...). This requires a sufficiently detailed break-down by end-uses of the model used, even if econometrics is the main approach.

These mixed approaches may be used in the various modeling frameworks described earlier : models of demand for electrical energy, multi-energy model or linked macro-economic and energy models.

2.2. General features of the methods actually used

2.2.1

Most countries refer to a **primary breakdown** of electricity consumption in three or four main sectors : residential, commercial (*) and industry (France, Australia, USA), with sometimes transport as a fourth sector (Netherlands, Italy), if not treated as a subsector of industry.

Consumption for specific uses such as public lightning, pumping or agriculture are sometimes delt with separately, often in a simplified way (trend extrapolation) ; this is the case for instance in France, Japan or the Netherlands.

Some variations may be observed around this main practice : one of these is Japan, which describes a slightly different approach in which the basis for the main breakdown of demand is the maximum power subscribed (<50 kW, 50 to 500 kW, more than 500 kW) and for the second category (small power : 50 to 500 kW) the voltage (low or high - 6 kV - voltage). But in practive the similarities with a residential/commercial/industry breakdown are very important.

An other is Sweden, where electric heating is not included in the consumption of the three classical sectors, but is considered as a fourth main sector (which is further split up in six groups).

2.2.2

For industry, there is most often a further breakdown in subsectors (for instance, 7 or 14 subsectors in the Netherlands (SEP), 25 in Sweden, 29 in France (EDF)). Particular attention is sometimes given to subsectors with high electricity intensities, which may lead to specific approaches . It is the case for instance for aluminium smelting in Australia, for petroleum, iron and steel, aluminium and railways in Japan, aluminium, iron and steel, chlorine and ammoniac in France. In some cases (e.g. for several sectors, including pulp and paper, in Sweden ; for aluminium and railways in Japan), the forecasts for these high intensity subsectors may be directly linked to planning or forecasting procedures of the level of activity of these sectors. The specific approach used may include a further breakdown by subsectors , by product (for instance for a large part of non ferrous metals and of chemestry in Italy) or by techniques (for instance for iron and steel in France).

2.2.3

For the **domestic sector**, a general reference is made to the number of households (or dwellings) and the average consumption per dwelling. The most common approach is the end-use approach, at least for the main electric appliances, and for thermal uses (air conditionning, water heating, space heating-sometimes with the distinction of several kinds of heating systems, as is done in Sweden and France).If some residential consumption remains, it is often treated in an econometric way.

(*)Sometimes described as other consumers, including the tertiary sector.

The method may be used for households as a whole, or in some countries (e.g. Sweden) make reference to the structure of households (family-size, number and age of children, urban and rural areas...) or (e.g. France or Sweden for space heating) to the kind of dwelling. The only country reporting the use, in the last few years, of a global approach of the average consumption per household (Australia) has been recently faced with a very sharp change in the rate of growth of this variable (from 30 % per year to 1 % per year). To try to explain this change, the utility is conducting a detailed survey, which could allow to distinguish consumption by end-uses and/or by categories of households.

2.2.4.

In several countries, it is the case that in the <u>commercial sector</u> the demand is increasing most rapidly, but also that forecasting this demand is most difficult.This difficulty is due in part to the uncertainty about the technical progress on electricity uses in these sectors. This point is stressed particularly by Australia, Netherlands and the U.S.A. It is also the sector for which the approaches (and the level of detail of the breakdown in subsectors or end-uses) are most different from one country (or utility) to the other, this being mainly linked to the availability of adequate data. Thus the approach may vary from global approaches (Japan), to approaches in which the commercial sector is broken down in several subsectors (8 subsectors in France, 12 categories of buildings in the E.P.R.I. Models , 16 categories in Australia (at local levels)...).

2.2.5

<u>Self Generation, or Combined Heat and Power (CHP) Generation</u> is an additional difficulty -and source of uncertainty - in forecasting the demand to the utilities themselves. Generally the main forecast concerns total power demand, and thus self generation or CHP is to be forecasted also, and deduced. This exercice is not easy, as firms are able to plan their activity in this domain only at a three to five years horizon, while utilities need 10 to 15 years ahead forecasts. It is also a sector in which the influence of future energy prices may be very important. The approach may be either global (Japan, France), or done at the level of subsectors (Netherlands). The Netherlands stress more particularly the magnitude of the uncertainty due to this factor.

2.3. - <u>Description of country practices</u>

2.3.1 - <u>Australia</u>

With regard to methods of forecasting electric energy consumption, the Sydney County Council in the case of domestic consumption carries out extensive surveys to obtain patterns of appliance consumption to use in conjunction with appliance saturation and projected housing developments. In the case of industrial consumption, surveys are made of major users to obtain details of projected developments and anticipated energy consumption. It has been found that for commercial development the relatively short lead time for projects renders surveys unsatisfactory.

2.3.2 - <u>Belgium</u>

The forecasting procedures in Belgium are very much decentralized, and therefore heavily influenced by the structure of the electricity sector. There are 4 generating companies enjoying regional monopolies. Each make its own forecasts. The planning of new equipments is however national, and thus based on the sum of company forecasts.

Each company has two types of customers :
- the large industrials, connected in 30 kV or above
- the distribution units.

The forecasts of future load for industrial customers is based :
- for short run forecasting on estimates made by the industrials themselves. They are questioned every year on their planned growth ;
-for longer run forecasting, the companies estimate the growth on basis of past trends plus additional information (shut down of plants or starts of new ones...).

The forecasts of the load for distribution customer units is subdivided into low and high voltage. Each distribution unit makes its forecast for those two categories. The forecasts are usually made by the manager of customer services. They are based mainly on past experience. Additionnal knowledge derived by the local managers from recent trends in lodgings and equipments may be inserted into the forecasts on a subjective basis.

2.3.3 - <u>France</u>

The forecasting model used by EDF belongs clearly to the end-use approach. Econometric relations are rare, and used for instance in the domestic sector to forecast a residual item in the demand related to specific uses of electricity, or as a check for the total of this demand, normaly delt with by end uses (6 categories of appliances + lighting).

Space and water heating is treated in great detail, with a breakdown into three different markets : new dwellings, first equipment , and substitutions in existing dwellings. In this last case, a further breakdown is done by kind of heating systems (direct heating and several categories of bi-energy systems).

In the tertiary sector, eight subsectors are distinguished. For each subsector, specific uses on one hand, space and water heating on the other hand, are treated separately. For these last uses, the modeling is similar to the one used in the domestic sector (new building, interfuel substitutions, different kinds of heating systems).

In industry, the consumptions of 29 subsectors are analysed by end-uses (5 types), but for three of them (non-ferrous metal, inorganic chemestry, iron and steel) with a further breakdown.

The model used two years ago delt only with the demand for electrical energy. It evolves now towards a multi-energy approach, already used for industry and (in a simplified way) for the tertiary sector. A multi-energy model for the domestic sector has also been built , and will be actually used for forecasting purposes at the fall of 1987.

2.3.4 - <u>Germany</u>

It exists in FRG a number of different methods, and of different forecasts, of electrical energy consumption, used or built either by institutes or by utilities. The forecasts may differ considerably from each other, which can be explained in part by the methods used, but mostly by the differences in the hypothesies used. For the eight utilities belonging to the "Deutsche Verbundgesellschaft", and representing more than 90 percent of power generation, the methods used remain often very simple, relying mainly on trend extrapolation - even if more advanced methods are used by some of them, including sectoral analysis, econometric-relationships and end-uses considerations-. In several cases, forecasts for the major industrial consumers are delt with separately, involving exchange of information with those consumers. Lastly, some utilities do not make directly a forecast of power consumption, but derive it from forecasts (most often based on trend extrapolations) of the maximum load and of its yearly utilisation-time.

2.3.5 - Italy

The model MEDITA used is of the "Medée" type, which can be considered as an end-use approach particularly well adapted for the building of scenarios. In industry, consumptions are derived from values - added at factor costs and electrical intensities. Products with high electrical intensities (a number of raw materials) are analysed in more detail . The tertiary sector is broken down in seven subsectors. The analytic approach of the tertiary sector is compared with equations relating electrical energy consumption to the number of employees and/or economic growth.

The domestic sector consumption is analysed by kind of appliances. Use is also made of a relationship between the number of inhabitants per dwellings and the income per head. For transports, the analysis is carried on with a great detail by means of transport, and the consumption linked to the volume of transport of goods.

2.3.6 - The Netherlands

In the Netherlands the long term forecast of electrical energy is based on a mixture of end-use and econometric methods. SEP uses the economic information of the Dutch Central Planning Board, completed with information of different industrial branches.

The industrial sector is split up in 7 categories if the econometric method is applied, and in 14 categories if the end-use method is used. In the end-use method, special surveys are made about the expectations of the big individual consumers of electrical energy. The outcome of both methods has to result in a coherent and consistent forecast for each of the industrial branches.

The forecast for the residential and commercial sector is based upon an end-use method. The residential demand is not split up in several housetypes etc... because there is hardly any electric heating.The commercial sector on the contrary is divided in 15 categories.

2.3.7 - Sweden

Different approaches are adopted in different consumer sectors, but the dominating method is to rely on end-use models in most of the sectors , i.e. in industry, electric heating and household electricity. In the tertiary sector (electric heating excluded) simpler form of econometric methods is used. The end-use models are complemented with consumer behaviour studies, mainly in the electric heating area.

The level of disaggregation is normally high : 10 to 30 sectors in industry, about 20 sectors in electric heating and about 20 to 30 sectors in the tertiary sector. For households electricity consumption , approximatively 30 different types of electrical equipment are studied.

At the national level, the method used deals simultaneously with the demand for the different kinds of fuels, and thus with explicit market shares assumptions. These assumptions are based on economic comparisons between competing systems and the former development of market shares. This multi-energy approach combined with an end-uses modeling framework is particularly necessary for the heating market, which is not easily delt with by econometric models.

2.3.8 - United States of America

Every conceivable type of electric energy forecasting method is employed in the U.S.A. Many of the smallest utilities still employ simple trend analysis. Small and mid-sized utilities often use an econometric-based model which may be disaggregated into residential, commercial and industrial sectors. Among the more progressive small utilities and for many large utilities, end-use and integrated engineering-econometric end-use models are growing rapidly in popularity.

Through the work of the Electric Power Research Institute (E.P.R.I.) in modeling and analysis, the constraints toward the use of these advanced techniques have been narrowed to the availability of data. Models estimated on national and regional data are available and data collection efforts are mushrooming as many utilities move to conduct surveys of their residential and commercial customers. To date, most disaggregation is at the end-use level (e.g., lighting, heating, cooling, cooking).

Current interest is in continuing work in disaggregation down to technology levels (e.g., all major types of lighting, types of heating, etc.).

3. CONCERNING LOAD, THE FORECASTS ARE GENERALLY LESS ELABORATED

3.1. Main features

From a theoretical point of view, it would be necessary for the planning of future generation capacities to have as an input a forecast of the whole load curve - i.e. hourly values of the load-, and information on the way this load curve may respond to random factors. However, only a few countries are able to make such a detailed forecast, which is reduced in some cases to a forecast of the annual peak demand (it is the case, for instance, for Australia or Belgium), or to the forecast of a limited number a characteristics of the load curve.

Forecasting the load curve needs in fact a very large amount of information on the load curves related to subsectors or to end-uses. This information is often lacking or insufficient. That is the reason why load forecasts are not frequently linked at a detailed level to the forecasts of energy consumption by subsectors or by end-uses. It is more frequent to compare energy demand forecasts and load forecasts, made independently, as a checking procedure (for instance in computing the utilisation time of peak demand, and analysing its trend).

Even if in some countries (in the USA for instance) it is commonly admitted that the forecast of the load curve is of secondary importance compared with forecasting of peak demand, a number of countries think that it is important to improve the detail of load forecasts, as well as the linkage between energy forecasts and load forecasts. To go in this direction, the most important task is to increase the amount of available data, in order to know more about the present and when possible about the past trends. In several countries (Italy or the Netherlands, for instance) work is in progress to develop load curve forecasting models using the detailed information obtained as an output of electrical energy consumption models. In the U.S., load shape forecasting models (such as EPRI's Hourly Electric Load Model) are available, and utilities are proceeding to compile information on load shapes by sector and end-use.

It is also stressed that in the forecast of load, uncertainty on power consumption forecasts will be increased by the uncertainties about the shape of the load curve, as well as by the random factors which may affect the load (and particularly the effect of weather conditions on load in general, and more crucially on peak load).

Regarding to those elements, the methods applied to forecast the loads may be very different from one country to the other .

3.2. Country practices in load forecasting

3.2.1 - Australia

Peak demand is derived from the total forecasted demand for electrical energy by taking into consideration the various factors likely to affect the load curve.

3.2.2 - Belgium

The computation essentially involves the annual peak demand. This one is computed by a division of the consumption by the foreseen utilisation-time. Load curves are assumed unchanged except for trends in the load factor, due either to the evolution of the load factor of a given category of consumers, or to the changing relative weights of categories of consumers with different load factors.

Random factors are taken into account by placing probability distribution functions as well on the demand as on the supply of the different production units. The criterion of acceptability of a given future mix of power plants is to limit the risk of shortage to a given number of hours per year at the confidence level of 0,95.

3.2.3 - France

A model allows one to associate to the annual power consumption forecasted for each sector or end-use (industrial subsectors, electrical appliances or heating systems, and the residual consumption of the residential and tertiary sectors which is not analysed by end-uses) a complete hourly stepped load curve. This model uses representative coefficients of seasonal, weekly and daily variations related to every sector of consumption. It takes explicitly into account the impact of temperatures on the loads associated with space heating end-uses. Its output consist in fifty simulations of the load-curve associated to the series of daily temperatures observed during the last fifty years. This output is then used, in a modified presentation, in investment optimization models.

3.2.4 - Italy

The daily peak of the charge on a working day is computed with the help of markovian processes for 14 time-periods in the year. For each of these time-periods are estimated the total energy consumption, and the average load for a working day. A probabilistic distribution of those loads allows then to derive a peak demand forecast for the time period.

A model that will utilize the sectorial forecast of the energy demand is now being elaborated. It will use statistical information coming from surveys conducted by ENEL on different kinds of consumers, at different voltage levels.

3.2.5 - The Netherlands

At the moment, the computation involves the annual peak-load. Because of a lack of sufficient information about the load curves by end-uses or by sectors , there is no possibility to forecast the separate load curves of the different categories of consumers. In the past it has been tried to get round this difficulty by forecasting the maximum-peak via autonomous regression procedures. Being without success, it was decided to use a forecast of the utilisation-time in order to forecast the maximum peak-load out of the energy-forecast.

In principle a forecast of the load in each hour of the year would be necessary. The activities in forecasting are aimed at this target.

When decisions concerning production are taken, the uncertainty about the outcome of the forecast has to be taken into account. This uncertainty is derived from the appeared deviations between forecasts and realisations in the past. It is a part of the reserve factor of the generation capacity.

3.2.6 - Sweden

Forecast concerning the load is deduced from the forecast in energy ; it concerns the peak and the hourly stepped consumption, for the different days and weeks. The forecast of the peak takes into account the influence of temperatures on demand for space-heating. The explicit linkage between forecasts of energy and forecasts of load does not systematically exist, but tends to be more and more frequently observed. Both regression based models with few explanatory factors and "addition of consumer group pattern-models" are used, but it is often a problem to get representative consumer patterns.

3.2.7 - United States of America

3.2.7.1 - Peak and load shape

Many U.S. utilities forecast the peak separately. The technique normally applied is to model the peak as a function of one or more variables, including weather, economic activity, price of electricity, price of major competing forms of energy and population. This model is then estimated form historic peak data.

Primarily as a result of a growing interest in Demand-Side Management, several new techniques for forecasting either the entire load shape or select seasonally or monthly weekdays/weekend days are evolving rapidly among U.S. utilities. They can be broadly categorized into disaggregated and aggregate methods.

Aggregate methods are generally based on a historic load shape constructed from use of weather-normalized previous years load shape. Load shapes are then disaggregated into major components, modified and reaggregated. Disaggregate methods attempt to forecast major elements of the load shape individually and sum them up to form the total shape. Both of these techniques employ methods to adjust the load shape to either match a separately developed energy forecast or become part of an hour-by-hour forecast. Each technique can use various principles of engineering estimation and econometrics in their execution.

3.2.7.2 - Uncertainty

In the last decade, U.S. utilities have become increasingly interested in uncertainty and risk. This presents two challenges to utility forecasters : how to account for uncertainty explicitly, and how to present the analysis to decision makers.

Most utilities now recognize that uncertainty may come from many sources, that the important driving forces must be identified, and that qualitative responses are generally important. More recently, most U.S. utilities have come to understand that uncertainty is now a permanent feature of the utility landscape, that successive changes in the domestic economy, in the world economy, and within the utility industry itself, will continue to affect the demand for electricity.

While many utility forecasters continue to rely on point estimates, some now represent the sources of uncertainty in their models. These companies have adopted probabilistic forecasting, a class of methods known for some time, but rarely used until now. A few utilities have experimented with scenario analysis, a technique previously used in the oil industry to analyze abrupt (post-OPEC) changes in its business-climate. Scenario analysis emphasizes the reasons for uncertainty, the underlying forces acting to cause changes in an economy. At the heart of scenario analysis is the construction of a detailed chain of events and forces that could produce a certain outcome.

4 -THE IMPACT OF ADMINISTRATIVE STRUCTURES

4-1- General features

In general, utilities are not free to decide on investment plans based only on their own forecasts and optimization studies. Demand and load forecasts - and also the assumptions on which these forecasts are based - have to be negociated with one or several social actors, and most often at several levels.The way these negociations are carried on depends heavily on the structures and organization of the power sector on one hand, of the State (Federal or not) and of the regional or federal administions, on the other hand. It is thus very difficult to make general statements on the form and effects of these negociations. The main issue is that these discussions and negociations play in fact an important role -even if more or less important depending on the country- in the actual planning of the power sector.

One level of negociation is the national one (in countries without federal structures). A first question is related to the assumptions used in the forecasts. Must the utility (or the body in charge of the coordination of the power sector) use the official economic growth forecasts, or its own ? Must it include "official" or "semi-official" targets for energy conservation in its hypothesis, or use its own judgement on the probability to reach these targets ? One can note that relying on official assumptions may lead in the first case to over-estimates and in the second to under-estimates. This question of assumptions may be complicated when there is no official assumptions on economic growth, and that several social actors defend diverging figures on these assumptions.

The degree of freedom of the power sector varies greatly from one country to the other. In a situation in which a national Government administration produces a forecast based on a "multi-energy approach", the role of the electricity production company is quite different from a situation in which the Government does not use such an approach. Is an electricity production company supposed to forecast total -and other than electricity- energy use, if the Government does so ? In fact, it is difficult for a power generation company to behave as if they produce a better forecast of the non-electricity part than the Government, especially when this Government is supposed to know more about these matters than the electricity production company.

With reference to substitution-possibilities between energy sources, the utilities themselves will have to admit that a multi-energy-approach is unavoidable in the various consumption categories where substitution is a valid possibility.

When the Government makes its own forecasts, the relation between Government and utilities brings about that the two forecasts are not allowed to differ subtantially. In this case, the Governement uses its forecast to define its energy policy. The electricity sector is subject to this policy. A strongly deviant forecast in this sector would not be approvable. A permanent discussion with the various administrative and economic authorities in the country is then necessary. This can in a limit case, of which the Netherlands is an example, lead to a take over of the proposals of the (in principle independent) power sector planning into the Governmental economic planning.

In other cases, the link between these two fields of planning is not so sharp. In France, for instance, discussions arises only every five years, in the framework of the preparation of the medium term economic and social plan. In between, discussions similar to those just described above involve only the administration and EDF, and are focused more on immediate decisions on investment than on long term load forecasts.

In countries without medium term economic planning procedures, the discussions will be more concentrated on issues involving only decisions to take in the power sector and their consequences. In countries with a federal structure this level of negociation may not exist, or be of limited importance, and found only at the level of States (US) or Länder (Germany).

A second kind of negociation exists at the geographical level, between a Federal State and the federated states, one federated state and state utilities, or between a national coordinating body and regional utilities (it is for instance the case in the Netherlands, where discussions between SEP and the eleven regional utilities are frequent , or in Sweden, where the 10 largest utilities discuss in a "reference group" the national forecasts prepared by a central forecasting group).

The forecasting procedure to be used depends on the relation with the various regional production companies. If the coordinating organ has a secondary function, the sum of the forecast of the regions will be chosen and the forecast of the coordinating organ will only be a check. If the forecasting activities of the regions are subsidiary to those of the coordinating organ, the "national" forecast will have a much greater impact.

Even in countries with a quasi-monopoly in the power sector (France, for instance), this kind of negociation is carried on inside the utility, between the general Directorate and regional departments.

In both cases, the improvement of the coordination process is aimed at through a better coherence in the various forecasting methodologies and also in the main hypothesis (energy, technology an economy related prospects...) used.

4-2- Country practices

4.2.1 -France

Discussions at the national level are intensive during the preparation of the national economic and social five years plan in the framework of the more general discussions which are then carried on about energy policy issues. Are involved in these discussions not only EDF and the administration, but also other social actors like the Energy Conservation Agency, other energy producers, trade unions, representativies of local (municipal) or regional authorities... The administration uses in this context a macroeconomic-multi-energy model (mini-DMS-Energie). Outside of this economic and social planning context EDF discusses each year its demand forecasts with the administration only, and those forecasts being in fact scenarios, there is -or at least there has been during the last few years-limited scope for diverging views.

At the geographical level , a coordination is done between regional and national demand forecasts. This coordination was previously carried on only through discussions and more or less arbitrary modifications of the regional forecasts (the sum of regional forecasts been generally higher than the national one). Now, this work is made easier by a model (PERCE) breaking down the national forecast at the regional level, and able to take into account specific hypothesis linked to the varying regional contexts and defined at the regional level.

The coordination is not done with such a precision for load forecasts, and is in fact complicated by the non-additivity of peak-demands, which does not permit to verify consistency at this level. Nowadays, modeling work has been undertaken to forecast hourly stepped regional and local load curves adding up to the national one. The use in this new model of the output of the PERCE model will allow a precise linkage between energy and load forecast at the regional and local levels as well as at the national one.

4.2.2 - The Netherlands

The forecasts concerning the electrical sector are based upon the official economic forecasts of the dutch government, prepared by the central planning board, as the planning department of SEP is not able to forecast by itself the economic growth. The economic figures are discussed with different industrial branches, to compare their opinions with the opinion of the government. It is possible for the electricity planners to deviate from the opinion of the government when the forecast seems to have been submitted to political influences.

However, the government itself makes also energy forecasts based upon the same economic figures, and the two kinds of forecasts are not allowed to differ substantially : in fact the final forecast of SEP has to gain approval of the Ministry of economic affairs. This context (close links with the central planning board for the choice of economic hypothesis on one hand, the need of an approval by the Government itself of SEP's forecasts on the other hand) - creates in fact very tight relations between national economic planning and the planning of the power sector.

At the national/regional level, negociations are also very intensive. SEP making its own forecast on one hand and the eleven regional utilities theirs, frequent discussions are necessary to insure a coherent national forecast.

4.2.3 - Sweden

The utilities can themselves decide on the economic forecast at the base of the electricity forecast. Official economic forecast is the starting-point but is normally modified, considering the opinions of industrial branches organisations of the federation of the Swedish industry and of different economic experts.

The National Energy Administration makes its own electricity demand forecasts. However, there is no direct negotiation between the government and the utilities related to electricity demand forecast . Indirectely the government energy policy affects the forecast by creating some basic assumptions on energy prices and conservation activities.

Internally within the utilities there could be a discussion on assumptions regarding pricing , marketing and future oil prices, as well as on the resulting forecast. The 10 largest utilities co-operate within an organization called KRAFTSAM, in order to avoid overlapping capacity and to get an optimal system for the whole of Sweden. One essential part of this co-operation is to make long range forecasts.

The work is lead by a "central forecasting group", which is reporting to a planning committee. Besides this central forecasting group, there is a "reference group" consisting of forecasters from the different utilities. In this group, discussions take place about the market development in different sectors and about the assumptions and preliminary results. Decisions are also taken on the type of statistical material and forecast that could be collected through the regional utilities or by the central group.

4.2.4 - United States of America

In general, utilities in the United States of America are involved with three possible levels which may directly influence the forecasts used in the planning process.

4.2.4.1 Federal

The federal government, through the Federal Energy Regulatory Commission (FERC) regulates certain interstate transactions of electricity sales and non-utility generation, and regulates the rates certain wholesale suppliers are able to charge to distributors who will resell the electricity. As such forecasts are reviewed and challenged or tacitly endorsed. FERC has also forced the state regulatory commissions to follow certain load management and rate making standards - thereby affecting the forecast considerably. In addition, the Rural Electrification Administration (REA) administers loans to rural electric cooperative utilities. REA loan applicants must forecast for review and approval. The federal government through the Department of Energy (DOE) has promulgated laws which impose national standards on building and appliance efficiencies . DOE has also administered programs which mandated certain electric utility conservation programs.

4.2.4.2 State/Regional

Nearly all states and the District of Columbia (Washington D.C.) have Regulatory Bodies which are charged with overseeing and approving all actions of most electric utilities. Some states exempt federal systems (TVA and BPA) as well as municipal and rural electric cooperatives. These regulatory bodies approve rate increases, and some issue certificates of need of power plants. Many states also have an Energy Commission whose role varies, but often includes promulgating state building codes, state appliance efficiency standards and, in some cases, issuing certificates of need. A few of these commissions produce their own forecasts which they urge utilities to adopt or refute. In the Pacific Northwest, a regional council exists which has a role in preparing a regional forecast and suggest regional conservation actions.

4.2.4.3 Local

Local (county and municipal) influence varies widely. A few counties and municipalities intervene in the regulatory process and offer critique of utility actions, including forecasts, which have an influence. Many electric utilities, which are owned and operated by the Body Politic and joint action agencies (a consortium of these municipal utilities) have governing boards or municipal councils which overview, critique and approve forecasts.

CONCLUSION

The methods used in electrical energy demand forecasting have improved considerably since the end of the 1960s. These methods tend to be more and more detailed (by subsectors or/and by end-uses) , more and more explicit (making clear the assumptions underlying the forecast) , and mixing engineering (end-use) and econometric approaches. The domain covered by the forecast is often increasing, and extends not only to power demand but also to demand for other fuels and even to macroeconomic growth.

According to the documents that have been forwarded to us, the forecasts of power seem to be the matter of less detailed investigations, and sometimes they are not directly linked to the forecasts of energy demand. At the present time, efforts are under way to create a logical linkage between the forecasts of energy and the forecasts of load, and also to extend this last forecast not only to peak demand, or to a small number of characteristics of loads, but to the whole hourly stepped load curve.

These domains of forecasting appear to be themes for a very dynamic modeling work, and the methods used evolve, and will continue to evolve, very rapidly.

A partly unexpected conclusion of this survey is the important weight of social or political factors in the methodology itself and in the choice of the forecasts actually used in decision making procedures . The planning of the power sector, including network planning, is not an issue only for a small number of specialized forecasters, but involves in fact all social and political forces. It deals not only with purely technical and economical explanatory factors, but also with voluntary actions as demand-side management, including energy conservation, load management , actions taken for market penetration . These issues offer a large scope for further studies on demand forecasting.

The survey suggests also a number of topics on which further work would be useful. Without pretentions to cover all interesting fields, one can quote at least four examples :

- comparison at a detailed level (end uses in the domestic or tertiary sectors) of assumptions used (unit consumptions, and their trends, future saturation rates...) and their links with socio-economic factors,

- methods (surveys) used to obtain data on load curves at a detailed level (subsectors, end uses) and comparison of the results obtained,

- methods used to forecast in the medium or long term the load (peak-load or load curve) at local or regional levels, and ways in which this information is used for network planning purposes,

- How to cope with random factors and uncertainty when decision making is concerned.

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