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FRAMEWORK FOR
ELECTRICITY TARIFF STUDIES

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FRAMEWORK FOR

ELECTRICITY TARIFF STUDIES

ABSTRACT

The paper on the Economic Analysis of Electricity Pricing Policies (P.U. Report No. RES 1) examined some of the problems and principles of electricity pricing. The present paper now suggests an approach to applying these principles. It is couched in terms of a series of 13 questions which will need to be answered in most cases, the significance of each being explained in some detail. The first six relate to the structure of costs, and the next three to the market for electricity, relevant distortions in the economy and the existing tariff structure. The tenth question asks what practicable cost-reflecting tariff might be introduced and is followed by questions about modifications necessary to meet financial and social objectives. Finally the ability of the utility to cope with a tariff reform is mentioned. No answers are proposed to any of the questions, the purpose of the paper being to suggest how missions or consultants might usefully undertake a tariff study.

For the readers' convenience, the questions raised in the text are also listed together in Annex 2.

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FRAMWORK FOR ELECTRICITY TARIFF STUDIES

Introduction

1. This paper sets out a series of questions of varying importance which it would often be useful to ask in studying the pricing policy of electricity enterprises from the points of view of economic efficiency and fairness, given a need to meet a certain revenue requirement. This study frequently demands investigation of the structure of marginal costs. The reason is that price is what it costs the consumer to acquire an extra unit of output while marginal cost is a measure of the value of the extra resources required to provide it. While there may be very good reasons for not equating these two things, i.e. strong arguments against pure marginal cost pricing, they should at least be looked at in relation to one another. To set a price below marginal cost is to make the cost to the consumer of buying it less than the cost imposed upon the enterprise (or the economy as a whole), and vice versa. His individual decision for or against purchase is then not related to the use of resources which his purchase will involve or which will be saved by his abstention. This needs justification in terms of its effects.

2. It follows that in many cases it is logical to proceed in two major steps. First the structure of marginal costs should be investigated, and then the pros and cons of setting price higher or lower be studied. But this may not always be the best procedure. In some cases, at least there where only the immediate future is considered, the barrier to expansion of output is not a high marginal cost but a physical or administrative limitation on capacity. In such circumstances, a high price is one way of determining who shall have a share in the limited supply, while waiting lists, priority rules and bribery constitute other ways. The problem is then to determine the best mix in the circumstances of the particular case.

3. One possible reason for setting prices above marginal costs, one which will arise when marginal costs are below unit accounting costs, is the need to provide a certain required revenues. If this, in any particular case, were the only reason, the aim should be to raise the extra revenue with the least possible effect on resource allocation. This would mean concentrating the excess of price over marginal costs on those components of demand least sensitive to price and on those parts of the price (rate) structure which least affect consumers' behaviour.

4. A possible reason for setting prices below marginal cost, on the other hand, is a desire to subsidise consumers. This may rest upon political or social judgements and the responsibility of making such judgements may or may not rest with the analyst. But at the very least it is important to distinguish whether a subsidy is proposed primarily:
- to encourage consumers to consume more;
- or to leave them with more money to spend on other things.

It can be argued, though not in each and every case, that a public enterprise's responsibilities should not include the second of these two. There are many other ways of redistributing income.

5. A third possible reason for setting prices unequal to marginal costs is that other prices may convey a distorted message and that it may seem right to attempt to offset them. Thus marginal cost to the producer may fall below marginal cost from the point of view of the whole economy when extra output requires extra foreign exchange and when foreign exchange is particularly scarce. The prices which consumers are willing to pay for the output may similarly be distorted by, say, heavy taxation of substitutes. The range of such possibilities is large, both with regard to costs and with regard to the demand side. In any particular case, the ones which are significant must be listed and examined. Here, there is only one general point to be made and this is that a distortion can be dealt with either by accepting its existence and offsetting it or by denouncing it and remedying it directly.

6. Yet other reasons may exist for charging prices which neither equal marginal costs nor serve to limit demand to the available supply. But in all cases the particular circumstances of the particular public enterprise will need to be considered. The following pages do not therefore attempt to give general answers to most of the questions which are proposed. Indeed the importance and relevance of these questions will vary from case to case. The only general and positive recommendations relate to the method of enquiry:

- Consider the effects of prices upon resource allocation, i.e. the incentives which they provide to consumers in relation to the structure of costs.
- Look for alternatives and weigh up their advantages and disadvantages as systematically as possible.
- Avoid both "conventional wisdom" and the assumption that the best practices in developed countries are also best in less developed countries.
- Be explicit about political and social judgments involved, whoever makes them.
Cost Analysis of Generation and Transmission

7. Once the plans for the future development of a power system to meet the projected development of the load are given (the shape of the system over the next few years is known in any case), the appropriateness of the present tariff structure can be considered. This, at its most general, is a question of whether existing tariffs adequately discourage loads with characteristics which impose a heavy cost upon the system or conversely, encourage those which involve a low cost. If they do not have such effects, then a change in their structure to introduce incentives of this kind may well be desirable. To charge a little for a load which imposes heavy costs may encourage wasteful use of electricity, while to charge a lot for a load which can easily and cheaply be met is to signal incorrectly to the consumer. Hence it is necessary to relate the incentive effects of the tariff structure to the cost and availability of supply. The relationships of the tariff structure to income distribution and to financial requirements, both very important, are left aside to start with.

8. What concepts of tariffs and costs are relevant? As regards the first, the answer is simple. From the point of view of incentives to consumers, what matters is what they actually pay and not what the electricity supply authority receives. Hence any taxes which consumers pay should be included in the study. As regards costs, in the present context of analysis in terms of the national interest, what matters is cost to the nation as a whole and not what the electricity supply authority pays for its inputs. This means that, where relevant, shadow prices rather than actual prices must be used and that taxes on inputs must be deducted and subsidies added back. If capital is scarce, its opportunity cost rather than the supply authority's borrowing rate should be used in discounting future costs in order to obtain their present worths.

9. Starting with costs, consider generation and transmission leaving distribution on one side for the moment. Information is required about:

- the incremental cost of energy delivered to the distribution system at times when an increase in generation will not run up against the security constraints;

- the times at which an increase in generation would bring the system up against the security constraints, (by lowering the generation reserve below its target level, by involving an unacceptably large loss of load should a transmission outage occur or by drawing down all water storage below the rule curves);

- the addition to all system costs resulting from adding to generation, transmission or storage in order to make possible increased generation at such times without infringing the security constraints.
More briefly, these three things are incremental energy costs; bottlenecks, i.e. capacity limitations; and the cost of removing bottlenecks by increasing capacity. In a partly or wholly hydro system, capacity may have a KWh as well as KW dimension.

10. Consider first the incremental costs of delivering more or fewer KWh at times when a small increase in output will not infringe the security constraints. These costs obviously vary with the level of the load and, in a mixed hydro-thermal system, may also vary, with the season. The aim should be to group together times within a season when the load will be approximately at the same level (e.g. winter nights, weekdays 12:00-14:00 etc). Each set of such times in effect constitutes a "step" on a daily, weekly, seasonal or annual load duration curve. Each will have an average incremental generating cost and it is this which needs to be estimated.

11. At times when an increase in demand would be met by increased thermal generation, incremental generating cost simply depends upon the incremental cost of the plant or plants which would provide the extra power and upon incremental transmission losses. The times in question will occur when thermal plant is on load:

- generating more than the minimum necessitated by a decision to avoid shut-down or to provide spinning reserve;

- but leaving more than sufficient to provide the desired reserve margin.

The incremental cost is then what is termed "system lambda" in discussions of economic dispatching (system operation) i.e. incremental generating cost per unit sent out, divided by one minus incremental transmission losses.

12. Normally, information about future incremental thermal generating costs should be available from the work of the engineering consultants in costing the operation of the system over a period of years in order to choose the least-cost alternative for its future development. But whether or not the programme is an optimal one, once it is known which plant will be operating at what levels of system load and at what times of the year, then the incremental costs can be estimated. Note that where there are several load centres and long transmission lines, these costs may differ between load centres.

13. When thermal plant is not in use, except at some minimum level, or when it is running at capacity, extra generation requires extra use of water. Incremental cost is then the incremental value of water, where water is measured in terms of the KWh it will generate. Here too, the right figures emerge from the sort of simulation of future system operation which is a necessary part of any sophisticated system planning study designed to select the best development programme. Where cruder methods have been used, a more direct approach must be taken. Since the information available and the system configuration vary so much from case to case, generalisation is difficult. Two examples relating to a mixed hydro/thermal system will show what is involved, still confining the analysis to times when there is spare generating capacity;
Extra hydro generating during a period when reservoirs are not spilling will require either extra thermal generation at some other time during that period or less spillage once the reservoirs are full. In the first case the incremental cost is that of the extra thermal generation; in the second case it is zero. The first case is typical of the "dry" or "discharge" season; the second of the "wet" or "filling" season.

It is also zero at times when water is being spilled.

Note that the right answer in principle is an average of all the conditions that could occur, each weighted by its probability.

Turn now to the second lot of information which was said to be necessary, that relating to bottlenecks. This is a matter of the times and/or load centres when it is anticipated that, under typical or average circumstances, a future increase in some customer's load would necessitate at least one of three things:

- a corresponding reduction of other customer's loads;
- a reduction in security below the chosen threshold;
- more generating, transmission or storage capacity.

In an all-thermal system with a seasonal swing large enough to accommodate all planned maintenance in the slack season, the only such time will be that of system peak. But where planned maintenance is spread throughout the year, many daily weekday peaks may be such times. In mixed systems energy (KWh) as well as capacity (KW) may be involved too, over periods when it is planned to use all the water that is available under normal conditions without drawing down the reservoirs below the levels chosen to give the selected degree of security. Thus just as in the case of incremental energy costs, the information required will reflect both the operating characteristics of the system and the time pattern of the load. In practice the information may relate only to anticipated normal conditions but, in principle, it is again a probability calculation of mean expectations which is the ideal.

The third lot of information required is the cost of adding to generating, storage or transmission capacity in order to meet extra load during the times just specified without either reducing other customer's loads or infringing the security constraints. Such an addition to capacity will often involve bringing forward projects which are planned anyway to meet a growing load, but it could, for example, simply involve plant specially designed for peaking. The point is to ascertain the extra costs of removing what were referred to as the "bottlenecks." This may be difficult in cases where the engineering consultants who chose and/or designed the scheme have not used a proper system-planning model. The reason is that the net cost of such additional capacity is
(i) the cost of adding to, or bringing forward plans for new capacity;

(ii) corrected for its effects on the subsequent costs of running the system over the next few decades.

(i) involves only construction cost estimates and a little discounting, but (ii) involves a simulation or optimisation model. Since many consultants do not, or cannot provide such a model, it has at present to be accepted that the third lot of information, an adequate systems analysis of the net cost of capacity additions, will not always be available. Hence the evaluation of a tariff structure may have to proceed using the first two lots of information plus only rough estimates of net incremental system capacity costs.

16. The need for the three lots of information can now be summed up in the following questions:

(a) In the light of the anticipated future mode of operation of the system under normal conditions as a function of the shape of the load curve and where relevant, of hydrology, how can the year be divided into periods and points of time?

(b) What are the incremental costs (measured from a national point of view) of additional KWh delivered to the distribution system at periods and places when supplying extra power under normal conditions will not infringe the security constraints?

(c) What are the periods or points of time and places where extra power cannot be supplied without infringing the security constraints and what would be the net addition to discounted system costs of expanding capacity to avoid such infringement?

17. These questions, and indeed all the following ones suggested in this paper, may appear to demand an impossible precision in their answers. But this would be a false deduction. Precise questions are intended to avoid ambiguity, and a rough and ready answer to them is all that can reasonably be expected from a brief investigation. Even lengthy investigation may do no better in many cases, because of an irremediable lack of basic data. The point is that an analysis which is logically clear but quantitatively crude can suggest tariff improvements which are important and well justified, even though they depart to an unknown extent from the unascertainable optimum optimorium.

Bulk Tariffs

18. Given the answers to these questions, it is possible to inquire:

(d) What bulk tariff structure would accurately reflect the cost and availability structure revealed by the answers to the last three questions?
This question implicitly asserts that a bulk tariff ought to reflect the cost and availability structure of generation and transmission in some detail. In contrast with the use of retail tariffs, the necessary metering involves too small a cost in relation to the size of the supply to constitute an obstacle. The positive reasons for a detailed cost-reflecting bulk supply tariff are as follows:

- an incentive is provided to the distribution management both to consider some reflection of the bulk tariff in retail tariffs and to concentrate load-building efforts in suitable directions.

- information is communicated pithily.

19. This last point is important in many ways. For example it enables distribution management to cost transformer losses, to examine the case for reactive power compensators, to estimate one of the main cost elements in rural electrification schemes and so on. Even for a generating authority with no bulk sales, calculation of a notional bulk tariff is essential for any examination of retail tariff level and structure.

20. In constructing such a bulk tariff one can start with the answer to question (b) i.e. KWh rates equal to incremental KWh costs for the various periods when, under normal conditions there is spare capacity so that extra energy can be supplied without infringing the security constraints. Periods which turn out to have fairly similar incremental energy costs can be lumped together. At other periods and points of time KWh rates will have to exceed incremental energy costs and/or KW rates will have to exist such that:

- they jointly make the tariff as high as is necessary to keep the load at these times down to a level which will just not infringe the security constraints, and/or

- they jointly measure the net addition to discounted system costs of supplying more power in such periods without infringing security constraints.

21. The first of these, the tariff which rations energy and capacity demands to match the bottlenecks, is more relevant, both as information and incentive, for the next few years. The second of these, the incremental KWh and KW costs of removing bottlenecks is more relevant for subsequent years. If the two differ, then the more tariffs are difficult to alter, the more should the second form the basis of tariff determination though non-price means of encouraging or discouraging demand in the next year or two may then have to be used. What any particular level of rates will do to limit demand is naturally difficult to measure. However it must be recalled that the load forecasts for the next year or two usually continue recent experience. If, to make up an example, the load has recently been pushing against some security constraint on winter weekday evenings, then it should be possible to predict whether the rise in capacity already under way for the next few years is going to outpace the growth in load at these times.
22. If it is, then a reduced tariff component in respect of such loads may be indicated. Conversely, if the bottleneck in question is likely to become tighter, then a tariff high enough to keep these loads within the security constraints will become higher than the existing one. Thus even without any definite knowledge about the responsiveness of sales to tariffs at least a little can be deduced.

23. What has just been said about existing tariffs really applies to any mix of KWh and KW rates in force during the relevant period which adds up to the same total charge for loads during it. Given this total, the problem is to get them right separately as well, remembering that while a KWh charge measures incremental cost or signals scarcity of energy during a period, a peak KW charge measures incremental system cost or signals scarcity of capacity at a point of time when system demand matches capacity less required reserves. While the period can be dated in advance, for example winter weekdays 17:00 to 19:00 from December 15 through Feb 28 excluding public holidays, the actual peak point of time cannot. Such a point can only be ascertained retrospectively. This makes unacceptable a system-peak KW charge when there is more than one bulk customer, as no customer would know (until afterwards) when he was paying for system peak KW. This difficulty will not arise if each such customer is charged on his own peak, but only in the rare event of complete lack of diversity will this provide exactly the desired incentive. Since what is needed is a message conveying information and incentive to the bulk customers in advance, resort could alternatively be had to spreading out the KW charge over all the potential peak hours. The charge on any one of these hours should then be proportional to the probability of its turning out to be the actual peak hour. This would amount to an extra high KWh charge during potential peak hours and the case for it is stronger the larger is the number of such hours in the year.

24. When a bulk tariff has to serve not only as a means of conveying information and incentive but also (for distributional or financial reasons which have yet to be discussed) as a source of funds for the generating authority a conflict may exist between the two sets of purposes. Suppose that a bulk tariff constructed along the above lines has to be supplemented by a certain total amount in order to provide the requisite cash flow or rate of return. Then the aim should be to achieve this with the least possible disturbance to its signalling and incentive functions. Three devices suggest themselves, of which the first necessarily exerts the smallest such disturbance:

- sharing out the excess charge between bulk customers on non-electrical variables, such as population or book value of net assets if they are distributing authorities;

- concentrating the excess on those components of the bulk tariff whose signalling and incentive effects are least, i.e. spreading the excess in such a way that all outputs are reduced by the same percentage;
- spreading the excess uniformly over all components of the bulk tariff, increasing them all in the same proportion, so that its relativities are undisturbed.

No general solution is possible, but it should be noted that providing an adequate answer to question (d) demands the exercise of ingenuity on these matters.

Distribution Cost Analysis

25. In order to proceed from the bulk to the retail level, it is necessary to examine distribution costs. Here too our concern is with engineering estimates of future costs and not with the accounting records of past expenditures.

(e) What is the structure of distribution costs?

26. A first step is to estimate incremental losses at different supply voltages and at different load levels in order to convert the bulk tariff rates into their retail equivalents. The second step is to estimate customer costs, a topic about which no more is said here. The third step is to examine the annuitised capital costs, plus associated future operations and maintenance costs, of:

- reinforcing the distribution system per KW of load growth in areas currently served;

- extending the system to new areas per KW of new load.

27. While the latter may have to be done ad hoc, there are several approaches to the former. In order of decreasing crudeness they are:

- relating past capital expenditure on distribution corrected for changing price levels and minus guesses of the cost of major system renovations and extensions, to the growth in retail demand at the time of distribution peak in areas currently served;

- relating growth in total length of each type of feeder, number of terminations and transformer capacity at each voltage levels to the growth in maximum demand at that voltage level, leaving out system extensions; the average growth in equipment per KW of demand is then costed at current price levels;

- finding the average cost per KW of reinforcement of each voltage level by costing a weighted sample of reinforcement schemes and then multiplying by the ratio of demand to capacity implicit in the chosen provisioning period to
get the average incremental cost per Kw of
demand of distribution peak.

In all three cases, the annuitised capital costs plus the associated annual
operations and maintenance costs can be set out per Kw of the relevant
maximum demand, without specifying exactly when it is going to occur.
Alternatively, they may be spread over Kwh in all the hours when it is likely
to occur. In this case, as with the similar bulk tariff analysis, the
result is to be interpreted probabilistically. Thus if a Kw cost of $10
is equally likely to relate to any one of 100 specified hours, the resulting
figure of 10% applicable to each of them signifies that there is a 99%
chance of the cost being zero and a 1% chance of it being $10 in any one
of them.

Schedule of Rates for Costing

28. Combining the notional bulk tariff with the information on
distribution losses and costs makes possible a reply to the question:

(f) What is the schedule of rates which can be
used for costing retail loads i.e. which
measures:

(i) the extra cost of delivering extra power
to consumers at times when this neither
infringes the security constraints nor
requires extra capital expenditure?

(ii) the charges which would have to be
levied at other times to keep the load
within the security constraints?

(iii) the extra cost to the nation as a whole
of expanding production transmission and
distribution capacity to meet an increased
load at such other times?

Note that if (ii) exceeds (iii) there is a strong case for expanding capacity.
But it is more useful to look at (ii) as having different time dimensions.
(ii) is a matter of restraining the load to match the capacity over the next
few years while (iii) is a matter of the cost of subsequent system expansion.
As argued earlier, which of them is relevant when they differ is a question
of tariff flexibility and of the importance of signalling a short-term or a
long-term message to consumers. If load-shedding commonly occurs at certain
times, then (ii) is in excess of the incremental charge for extra electricity
which the existing retail rate structure would involve. It is worth
repeating too that in the cost studies used to answer (i) and (iii) rough
but relevant information about the future is more relevant than precise data
from the past. Great care must be taken in using accounting records to
ascertain which pro-rated overheads are included in particular items of costs,
since such allocations may (not surprisingly) be inappropriate for the present
analysis for which they were not designed.
29. Let it be clear that the schedule of rates used for the casting of retail loads is no more than a collection of information necessary for examining tariffs. Metering and billing problem alone would prevent its implementation as an actual rate structure for all consumers. But does provide necessary information for constructing feasible retail tariffs and for costing new loads. Before we get on to tariff construction it is worth pausing to note that a distribution undertaking can influence its customers not only via retail tariffs but also by its encouragement or discouragement of particular loads. An "active marketing" posture of this latter sort may be uncommon among electricity authorities, but is to be commended for all that.

Load Analysis

30. The next step is to find out as much as possible about the composition of the load i.e. who uses how much electricity, for what purposes, when:

(g) What information can be assembled about the separate load curves of the different groups of customers, the split of their consumption between different uses and the time pattern of these uses?

When quantitative information is lacking, merely qualitative information must suffice. Knowledge of factory hours, people's eating habits and the time it gets dark are of some use. Suggestions that quantitative techniques ought to be applied in the future may not come amiss.

Price Distortions

31. Using this information it is then necessary to ask which of the various uses are affected by the availability and price of:

- other fuels,
- electrical appliances

Thus one can find out whether gas competes with electricity for cooking, whether some industrialists generate their own electricity, the importance of other sources of motive power, the tax on air-conditioners and so on. The aim is first to understand these matters as factors helping to determine the pattern of electricity usage and, secondly, to see whether correction of these prices to allow for taxes, shadow exchange rates and the like would make them substantially different. If so, then they constitute misleading incentives. If nothing can be done to change them, then it may be worth considering ways in which the incentives provided by electricity tariffs could be slanted so as to produce an offsetting effect. Two imaginary examples will show what is meant:

- if gas competes with electricity for certain peak-intensive uses, if rates for gas are heavily subsidised and if nothing can be done about it, any case which there might otherwise be for changing high peak rates for these uses of electricity may be weakened;
- if private enterprises obtain generous tax relief on all capital expenditure including auto-generation, then perhaps there is a case for lower electricity tariffs for large industrial users than there otherwise would be.

32. Summing up, the question must be asked:

(h) Are price distortions in other parts of the economy likely to affect electricity sales importantly; if so, can and should these distortions be remedied; if they cannot or should not, should electricity tariffs be slanted in order to offset these distortions?

Slanting the tariffs in this way may well prove to be too complicated, may conflict with notions of fairness or may interfere with other broad government policy objectives. Nonetheless it is right to consider this problem and include it as one of the factors in a critique of the present tariff structure. The difficulties involved in any such slanting furnish an argument in favour of tackling the distortions directly. The same applies to distortions which make marginal cost to the electricity supply undertaking differ significantly from cost from the national economic viewpoint.

Existing Tariffs

33. Next, the present tariff structure must be described. Such problems of administering it as cost, complexity and fraud must definitely be considered but in the present context the main question is:

(i) What is the present tariff structure and what incentives does it provide to consumers?

34. Another way of expressing this is to ask what are the partial derivatives of consumers' electricity bills with respect to their electrical behaviour. A few examples will show what is meant by such a description:

- extra KWh cost the same by day and by night;
- a uniform monthly maximum demand charge offers no greater incentive to keep demand lower in the peak months of demand than in the rest of the year;
- penalties for low power factor apply only below 80%;
- a lower domestic rate for "heating" than for "lighting" with separate meters and circuits makes extra KWh dearer for lighting than for other domestic uses;
- a flat rate of 3¢ for users consuming up to 150 kWh per month, and one of 4¢ for users consuming more, strongly encourages small users to keep their monthly consumption below 150 kWh;

- descending block rates make the cost to the small consumers of an extra kWh 5¢ as compared with 3.5¢ for large consumers.

These examples are purely anecdotal, to show what sort of incentive effects can exist, but what is required by way of answer to (i) is naturally a systematic description.

**Tentative New Tariffs**

35. With all the information collected in answer to the questions it is now time to ask:

(j) How can the tariff structure be changed so that the incentives it gives correspond more closely to the schedule of rates developed for the costing of loads?

36. This question will not produce a final proposal for a new structure since income distribution and financial problems are still being left on one side, as are the problems of transition to a new structure. But at this stage it is certainly necessary to allow for:

- Any strong arguments for slanting the tariff structure developed under question (h).

- Practicality and cost. If the existing tariff is difficult to administer, conducive to disputes or prone to fraud, ideas for making it better in these respects will be useful and must be allowed to help determine the choice of the new tariff structure.

37. There is, of course, a trade-off between the cost of administering a tariff structure (which depends largely on the cost of metering and billing) and the extent to which it can reflect the structure of the schedule of rates for the costing of retail loads, so providing appropriate incentives. Five rather general but useful propositions about this trade-off can be advanced:

- As the extra cost of more complex metering has to be justified by the effect of the superior incentives it can present, and as this extra cost rises but little with the size of the consumer, while the absolute response to incentives rises quite fast with the size of the consumer, the case for more complex metering is relatively stronger the larger the consumer.
As the response to incentives is greater for uses which are not time-bound and where there are alternative sources of energy, complex metering is best justified for consumers for whom such uses are important.

The option between a simple tariff and a more complex more expensive one can often be left to the consumer by allowing him a choice of tariff. With such options, the consumer who could respond strongly to the incentives of the more complex tariff should find it to be the cheaper one, even though he has to bear the extra cost of the more complex metering.

There is often a choice between a larger number of simple tariffs and smaller number of more complex ones. Thus if night KWh are shown by the schedule of rates for the costing of retail loads to be, on average, much cheaper than day KWh, and if night KWh form a smaller proportion of shop than of domestic consumption, a two-rate night-day tariff will cope with both. The alternative would be to have a separate single-rate tariff for each, with a higher unit charge for shops.

With monthly meter reading, seasonal KWh tariffs can always be introduced at a negligible extra cost. Such tariffs should, therefore, always be considered when demand and costs display a significant seasonal pattern.

An improved tariff structure, once achieved, should be designed to last for a number of years, apart from adjustments to inflation, since the responses to incentives involving the design and the growth in ownership of appropriate appliances are spread out over time. This, it will be seen, is an argument for concentrating on (iii) rather than (ii) in question (f), i.e. for looking at long-run costs - at least when there is no acute shortage of capacity necessitating a lot of load-shedding. A statement that 10% of residential consumers buy less than 100 KWh per month, for example, is less interesting than a forecast that, in five years' time, the figure will be only about 15%. The incentives should be directed at tomorrow's consumers rather than at today's, except when today's problems are particularly acute. When they are not, an attraction of optional tariffs becomes important. Suppose, for example, that a time of day tariff can give much more relevant incentives than a straight energy tariff. However it does cost more, so that its immediate introduction for all consumers would not be worthwhile. In these circumstances it might be introduced as an option to which, initially, only a minority of consumers might subscribe. As individual loads grew, then, with effective marketing, more and more consumers might subscribe and the relationship between the two tariffs could gradually be tilted so as to favour it. But if the course of events showed that its wider adoption was not after all worthwhile, it could be discouraged or even suspended (subject to a right for existing consumers on it to continue) and little would have been lost.
39. Except possibly for large industrial consumers, it is to be expected that the revised or new tariff structure proposed will not reflect most of the details of the schedule of rates for the costing of retail loads by which it is inspired. Thus the new tariffs will contain only a very few of all the possible incentives to economise more in the use of electricity at some times or in some uses than at other times or in other uses. It is, therefore, important to see that those few incentives which can be put in the tariffs are those which matter most. What matters most is proportional to:

- the size of the incentive suggested by the schedule of rate for the costing of retail loads, and
- the magnitude of the response.

Thus a signal that peak KW cost a great deal more than other KW may be less useful than a signal that night KWh are somewhat cheaper than day KWh if the response to contribution-to-system-maximum-demand pricing would be much less than the response to a lower KWh rate at night. If water heating is the most promising subject for domestic tariff incentives, however, telecontrolled water heaters with a special cheap rate and a separate KWh meter may be more appropriate. Similar sort of considerations affect decisions about industrial tariffs. Thus if shift-working is insensitive to electricity charges, it may be better to concentrate on selling interruptible supplies to industry than on cheap night KWh. In most cases, as argued in the previous paragraph, the response which is relevant is not the immediate one but the response over a period of years, so that the relevant schedule of rates for costing retail loads must correspondingly, relate to the average over a future period of years. Only when power shortages are acute and are not going to be remedied for a few years is concentration on short-run load-restraining tariffs to be preferred.

Finance and Income Distribution

40. Any set of new tariffs (and the new consumer classification which they may well involve) tentatively developed along the foregoing lines now has to be modified to allow for:

- financial requirements;
- any desired income redistribution;
- the problems of making the transition

Although these interact, it is expositionally convenient to consider them separately.

41. Taking financial requirements first, these are that the electricity tariffs generate sufficient cash flow, a requirement often translated into rate of return terms. In addition, a government may wish to tax electricity consumers to provide general revenue. This is perfectly reasonable; indeed if other fuels are taxed it may be necessary to tax electricity too in order
avoid a distortion in the relative prices of electricity and other fuels. Circumstances obviously vary between countries too much for generalisation to be possible, but the first step is clearly to inquire:

(k) If the tariffs tentatively developed so far were applied, how much revenue would they yield and is this sufficient?

4.2. It may be thought that tariffs based on the schedules of rates for the costing of retail loads, including connection and/or fixed charges to cover customer costs, will normally fall below accounting costs, so that the revenue produced would be sufficient. But this is in fact far from necessary. For one thing, if inputs are valued at shadow prices, costs looked at from the point of view of an electric utility may be considerably exceeded. But such national economic refinements may be outside the scope of a tariff investigation. The main point which applies to all systems which have existed for any length of time is that accounting costs reflect past capital expenditure and the chosen depreciation rules, whereas any capital costs entering into the analysis relate to expected future expenditure. There is an ongoing race between inflation and technical progress, the one raising and the other lowering future capital costs relative to past capital costs. Furthermore, even when the schedule of rates for the costing of retail loads reflects only generating costs plus losses, these are incremental costs. With plant loaded in "order of merit" these will usually exceed average generating costs, so a tariff based on them will yield an excess of revenue over generating costs which may or may not suffice to cover all other costs. Thus there is no general presumption either way about the answer to (k).

4.3. If more revenue is required, then the argument follows similar lines to those set out earlier concerning bulk tariffs. Subject to any reservations relating to income distribution, the aim should be to increase the level of tariffs with the least possible disturbance to the incentives which they present to customers to go easy on consumption at times or places when incremental costs of energy are high and/or when extra KW push against the security constraints or necessitate extra capacity. This involves concentrating the increase on those components of the tariffs which will elicit the smallest response by way of change in consumption. Fixed charges are an obvious first target. They do not necessarily have to be uniformly high. For example they could be related to property value as assessed for tax purposes. The same considerations clearly apply if less revenue is needed.

4.4. Income distribution decisions are difficult for consultants to cope with, since they involve political and social judgements which may be outside their competence. But someone, depending upon the circumstances of the case, must make them, and, once made, they specify:

- who is to benefit;
- who is to pay;
and the problem is to decide how. They can be elicited, and justification of them sought by asking what distributional objectives entered the existing tariffs, if any. Two cases must be distinguished:

- the aim is to stimulate the consumption of a particular group of consumers i.e. to achieve an incentive effect;

- the aim is merely to reduce the bills of a particular group.

45. An example of a subsidy is the provision of rural supplies at tariffs below the cost which can be calculated for rural loads using the schedule of rates for the costing of retail loads (which embodies the capital costs of extending the distribution system). This may be done simply by requiring rural tariffs to be the same as urban tariffs, in which case there is no more to be said. But in other cases, where the nature of the subsidy is an open question, the aim must be to provide any desired incentive without producing other unwanted incentives. Thus a low rate on a first energy block will reduce the bills of the consumers on the tariff. This will have different incentive effects according to whether the consumers on the tariff in question use less or more than this amount of energy. Hence a lower fixed charge might be considered if what is aimed at is merely a financial benefit.

46. The changeover from one tariff structure to another is always difficult, since customers who did well under the old tariff tend to regard themselves as having a vested interest in it. Hence the impact effect of the changeover and possible tactics for making it more acceptable are problems of some importance. The transition may need to be made in several stages and it may be a good idea for the new tariffs to be introduced only as options.

47. All these matters deserve thought and investigation. To sum up, it must be asked:

(1) Given the answer to question (k) and given the amount of any overt subsidies, how can the tentatively-determined customer classifications and tariffs be modified to provide the required revenue and implement the desired subsidies with the least possible distortion of incentives?

48. The phrasing of the question is not meant to imply that all proposals for income redistribution and subsidisation should be automatically accepted. For example, while nationally uniform tariffs are obviously simple and appear to be fair, it is not at all obvious that the resulting equal incentives to load growth make sense in terms of resource allocation. Perhaps electricity-intensive industries should have an incentive to locate near generation centres. The magnitude of regional differences in the schedule of rates for the costing of retail loads should at least be set out and considered before any decision to ignore them is made. Another example of conventional wisdom which requires a second look is the notion in some countries that poor electricity consumers should be subsidised. Here it is worth noting that poor people without electricity are worse off than poor people who have it.
Hence the idea of subsidising the poor in some other way than via electricity deserves attention.

**Institution Building**

49. Whatever professional competence on electricity authority displays, it cannot be taken for granted that it is animated by considerations of the national economic interest. It may judge changes in tariff structures by their immediate public acceptability among the influential, valuing a quiet life more highly than economic effects. It may, alternatively, want to promote peak demand so as to justify more rapid expansion and engage in empire-building. Such attitudes are a luxury which a poor country can ill afford, so it is worth asking:

(a) Is the client electricity administration both properly motivated to further the economic development of its country and technically capable of examining economic issues?

**Final Remarks**

50. The reader of the preceding pages will have noticed the obvious point that the questions proposed will often be rather too general to match the particular circumstances of any particular study. But while the letter of the analysis will need modification from case to case, the spirit of it applies everywhere. Prices can and do affect the attractiveness to consumers of alternative courses of behaviour and so need to be related to their consequences for resource use, consequences measured in terms of a forward-looking concept of costs. This is as much, or more, a matter of the structure of prices and costs as of their levels.

51. Simple and general propositions about pricing cannot be made. But it is usually a good idea to ask whether prices should not be cut at times and places when more could easily be supplied because capacity is under-utilised. Similarly, when capacity limits are strained it is worth considering whether a rise in prices might limit demand more efficiently than interruptions of supply, rationing, etc.

52. Pricing, as well as being a means of raising revenue, is about future choices in relation to future costs. This means that the relevant figures are only estimates and are subject to uncertainty. There is therefore a temptation to go back to accounting cost figures. But an accurate record of the past is not relevant; rough and uncertain estimates about the future are unavoidable in decision-taking. Accounting costs, on the other hand, are relevant for total revenue requirements.

53. Politics may demand that pricing policy should aim to achieve some measure of income re-distribution. This may have to be accepted but the analyst should at least ask whether other methods are not better.
1. Less developed countries cannot afford the same quality of service as developed countries. An application of this obvious point related to the provisions made to ensure security of electricity supply.

2. Any project for the expansion of power capacity normally constitutes the next step in a whole proposed programme for the development of a power system. This programme is asserted to be the minimum-cost way of meeting the projected load, subject to certain constraints relating to the security of supply. Two simple illustrative examples of such constraints are:

   - there must be enough generating capacity to withstand the loss of the largest single generating unit without output falling below the predicted peak demand;
   - water storage capacity and thermal capacity must together be sufficient to meet predicted energy requirements in the critical period even if the inflow is as low as in the driest season experienced since records began.

3. The probability of interruptions of supply is often not calculated by the engineering consultants responsible. This would require data about the weather sensitivity of consumption, plant outage risks and the range of forecasting errors, as well as about the variability of water flows (where hydro-power is involved). Nevertheless, even without a probability calculation, it is obvious that if the constraints were less stringent:

   - there would be a cheaper minimum-cost programme to meet the projected load;
   - the probability of interruptions of supply would be greater.

4. Hence the question arises of whether this saving in cost (which can be readily calculated) outweighs the disadvantages of the greater probability of interruptions. Even if the latter is calculated too, this question cannot be answered purely objectively because of the problem of putting money values on interruptions of supply. But this does not justify ignoring the question. It is necessary to gather whatever information can be obtained and use it to form a judgement. Continuing the simple example given above, more relaxed constraints could be considered, such as:

   - ability to withstand outage of the second largest unit;
   - meeting energy requirements in the second driest season experienced in the past.
5. The resulting cost-saving could then be calculated and estimates made of how much load shedding would be required if

- outage of the largest unit occurred;
- a season as dry as the driest experienced in the past occurred;

assuming correctness of the load forecasts. This would give a rough idea of the order of magnitude of the possible disadvantages of the reduction in security. It might be expressed in value terms by using a "penalty price" per kWh of supply failure. A judgement could then be made as to which of the two levels of security was the better choice in the circumstances of the country in question. The system's arrangements for load control and load-shedding obviously figure among these circumstances and their adequacy would have to be investigated.

6. Generalising from this example, a question can be formulated as follows:

(n) How do the possible consequences of a lower degree of security compare with the cost savings it would involve, given that load-shedding arrangements are made as good as possible?

This question should be applied to investment in transmission and distribution as well as to investment in generation. It might, for example, lead to a judgement that suburban distribution networks should be provided with relatively less security than urban networks.
ANNEX 2

List of Questions Raised in the Text

(a) In the light of the anticipated future mode of operations of the system under normal conditions as a function of the shape of the load curve and where relevant, of hydrology, how can the year be divided into periods and points of time?

(b) What are the incremental costs (measured from a national point of view) of additional KWh delivered to the distribution system at periods and places when supplying extra power under normal conditions will not infringe the security constraints?

(c) What are the periods or points of time and places where extra power cannot be supplied without infringing the security constraints and what would be the net addition to discounted system costs of expanding capacity to avoid such infringement?

(d) What bulk tariff structure would accurately reflect the cost and availability structure revealed by the answers to the last three questions?

(e) What is the structure of distribution costs?

(f) What is the schedule of rates which can be used for costing retail loads i.e. which measures:

(i) the extra cost of delivering extra power to consumers at times when this neither infringes the security constraints nor requires extra capital expenditure.

(ii) the charges which would have to be levied at other times to keep the load within the security constraints:

(iii) the extra cost to the nation as a whole of expanding production transmission and distribution capacity to meet an increased load at such other times?

(g) What information can be assembled about the separate load curves of the different groups of customers, the split of their consumption between different uses and the time pattern of these uses?

(h) Are price distortions in other parts of the economy likely to affect electricity sales importantly; if so, can and should these distortions be remedied; if they cannot or should not, should electricity tariffs be slanted in order to offset these distortions?
(i) What is the present tariff structure and what incentives does it provide to consumers?

(j) How can the tariff structure be changed so that the incentives it gives correspond more closely to the schedule of rates developed for the costing of loads?

(k) If the tariffs tentatively developed so far were applied, how much revenue would they yield and is this sufficient?

(l) Given the answer to question (k) and given the amount of any overt subsidies, how can the tentatively-determined customer classifications and tariffs be modified to provide the required revenue and implement the desired subsidies with the least possible distortion of incentives?

(m) Is the client electricity administration both properly motivated to further the economic development of its country and technically capable of examining economic issues?

(n) How do the possible consequences of a lower degree of security compare with the cost savings it would involve, given that load-shedding arrangements are made as good as possible?