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PLANNED REDUCTION IN ELECTRICAL ENERGY USE
IN NASHVILLE - DAVIDSON COUNTY, TENNESSEE:
A PRELIMINARY ASSESSMENT

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Abstract

An assessment was carried out of the impacts of the various alternative strategies designed to reduce the rate of electrical energy use in the Nashville-Davidson County area, in the light of a potential crisis in supply. Seven strategies were identified among the major categories of voluntary reduction, price regulation, and mandatory reduction. Thirty-three sub-sectors were identified among residential, commercial and industrial users, and the consequences of imposing the strategies were assessed using a cross-impact matrix. The value of the methodology as an aid to public policy formulation lies in its possible extension to allow direct participation of various affected publics.

1. INTRODUCTION

As the demand for electrical energy continues to increase in the face of uncertain prospects for supply availability, the probability increases for a local or regional crisis requiring reduction of electrical energy use by consumers. Indeed, instances have arisen in which governmental agencies and utilities have been forced to stimulate conservation by various means of a more coercive nature than simple appeals to the voluntary spirit. As coal, petroleum, and nuclear energy sources continue to enjoy an uncertain future, we may again face such instances of forced reduction of usage.

Our purpose is to assess the impact of various alternative reduction strategies, one or more of which might be adopted in a crisis, upon various sectors of the consuming public, using supply and demand characteristics of Metropolitan Nashville-Davidson County, Tennessee as the unit of analysis.* These are the basic questions which must be addressed: What strategies are generally available to affect reduction in the residential, commercial and industrial sectors of the consuming public in this region? How effective is each strategy likely to be in each sector? What are the social, economic, political and technological impacts of each strategy upon individuals and institu-

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In addition to the authors of this paper, participants in the initial study were Professors Daniel M. Brown, Robert T. Nash, William Y. Smith, Francis M. Wells, and John W. Williamson. Other student participants were Jeffrey T. Delargy, Joseph H. Johnston, George A. Olive, Jr., John E. Pike, C. Vincent Schmidt, Alan B. Weatherly, and Cathy Wilson. The work of this group was assisted by an oversight committee involving representatives of business, industry, academia, and consumer organization.

The preliminary impact analysis of the task group, available from the Vanderbilt University Engineering School, Nashville, Tennessee, contains the material presented in this paper, as well as further explanation of the origins of the project and useful graphic presentation of some of the information contained herein. (See Reference 1.)

tions, both public and private? Finally, is it possible to facilitate public discussion of this issue that will contribute to formation of a broad consensus on the most desirable policy choice for planned reduction?

Answering these questions in any region or locale involves at least three principal tasks, which are addressed for the Metro Nashville area in the next three sections of this paper. First, the case histories of similar occurrences should be studied with a view to assessing the actual efficacy of the strategy selected, as well as identifying unique characteristics of that situation which may have increased or decreased the effectiveness of the effort - but which might not be present in a crisis situation in the Metro Nashville area. Such a review logically leads to specification of the unique characteristics of Metropolitan Nashville-Davidson County, including social, economic, legal-political, and technological data. Finally, selected strategies are assessed in terms of their impact upon these characteristics, and upon people and groups within the consuming public. Hopefully, this form of organization can be repeated by interested parties in any locality.

2. HISTORICAL REVIEW OF PLANNED REDUCTION EXPERIENCE

When considering planned reduction of electrical energy in Nashville, the experience of other areas which have had such reductions provides some insight into possible impacts. Drought, a coal-miner's strike, and the oil embargo necessitated planned reductions in the Pacific Northwest, United Kingdom (Great Britain), and Los Angeles, respectively. The remainder of this section describes the measures taken and some of the resultant impacts.

2.1 PACIFIC NORTHWEST[2]

The lowest rainfall level in 95 years left Washington and Oregon in 1973 with a 7.4% decrease in the absolute amount of electricity available. The shortage was projected to last at least until May, 1975. Various measures were taken. For example, there was a 68° F. heating limit for state agencies, and alternate street lights were turned out. Appeals to practice energy conservation measures (the Kill-a-Watt Program in Seattle) reduced overall demand by 8-9%. In Oregon aluminum plants laid off some 1000 of 4000 employees. A ban on outdoor advertising was put in force. Daily instead of nightly cleaning of buildings resulted in heating and lighting bills some 14% less than normal. Measures such as lower wattage bulbs in office buildings and lower hot water temperatures resulted in commercial electricity savings on the order of 10-20%.

In the Pacific Northwest, most power generation is hydroelectric; long-term shortages such as the one described are generally chronic problems and have only meteorological remedies, unlike the acute problems which can strike the Tennessee Valley region. Longer lead-time programs of consumer education and emphasis on volunteering have a better chance in such instances; also, the amount of load reduction needed is generally smaller.

2.2 UNITED KINGDOM[3]

A sharp fall in coal supplies to British power stations--nearly 40% below the expected level--led to the adoption of emergency measures in the electricity consumption sectors in December of 1973. Restrictions applied to the commercial and industrial classes were the following:

(1) no heating of commercial premises above 63° F.
(2) lighting cut 50% in shops, offices, and other premises
(3) electricity supplies limited for industrial and commercial users to three consecutive days per week according to a schedule drawn up in each area and no work beyond normal operating hours was permitted
(4) firms using non-interruptible processes were limited to 65% of their normal electricity consumption per week.

An S.O.S. (Switch Off Something) program in the residential sector resulted in about a 20% reduction. In spite of an electricity supply 40% below normal, industrial production as of February was reduced by less than 30%.[4] Employees in the production industries numbered 9.68 million in November and about 9.55 million the following February.[5]

As in the Pacific Northwest, British power plants are basically of one type; namely, in this case, fossil fuel steam turbines, with negligible hydroelectric and nuclear generation. Most British problems are attributable to shortages of petroleum or labor unrest amongst coal miners. Both supply problems, unlike the Pacific Northwest, are basically acute, and subject to alleviation by government policies.

2.3 LOS ANGELES

The greatest part of Los Angeles' electricity is produced by burning fuel oil. As of October, 1973, the city had contracts for 48% of its requirements from Middle Eastern sources. Because of the embargo, emergency action was necessary to curtail the use of electrical energy. Measures implemented resulted in a 17% reduction in electrical energy use. The specific legislative response[6] as well as the highlights of a report issued by the Los Angeles Energy Coordinator[7] are detailed in the remainder of this section.

The purpose of the "Emergency Energy Curtailment Plan" was to minimize the effect of a possible shortage of electrical energy on the residents of the city and to adopt provisions that would "significantly reduce the consumption of electricity over an extended period of time, while reducing the hardship on the city and the general public to the greatest extent possible."[6] In order to accomplish these goals, a variety of measures were undertaken; all, however, subject to the proviso that power necessary for public safety, security or essential government services was to be exempt. Major actions were the following:

(1) Residential users were to cut use by 10% in comparison with a year-ago base period. This did not apply to customers who were in the lowest third of residential users as determined by number of kilowatt hours (KWH) consumed in the base period.

(2) Commercial users were to reduce by 20%.

(3) Industrial users were to reduce by 10%.

Additional provisions were: a 25% reduction in street lighting; prohibition of outdoor advertising and decorative lighting; reduction of 50% in floodlighting of service stations, used car lots and similar establishments; temperature restrictions on heating to 68° F. and on air conditioning to 78° F.; and a 25% reduction in lighting of outdoor public exhibitions such as sporting events. Penalties were a 50% surcharge on the electric bill for the first violation, a 2-day interruption of service for the second, and a 5-day interruption for the third offense. Relief could be granted by the Department of Water and Power or by a system of appeal boards if curtailment would result in unemployment, if during the preceding year technological improvements had been made to the customers' premises, if occupancy changed, or for similar reasons.

Certainly the plan averted the spectre of rolling blackouts and a significantly reduced work week. As implemented, it did not appear to cause an "unacceptable level of economic dislocation or personal hardship."[7] This was, however, a curtailment and not a conservation program. There was a limited amount of electricity to sell and the aim was to keep use within certain limits, not merely to make use more expensive.

Although factors contributing to the success of the program (a 17% reduction in use) are not totally understood, it is believed that the mandatory nature of the ordinance contributed to some 10 of the percentage points of reduction. Voluntary curtailment programs in neighboring areas (such as Southern California Edison) and around the country average under 5%.

A recommendation was made to increase the "minimum exemption level" from the lower third of the residential customers to the lowest 60% (thus exempting all those who use less than 800 KWH per month). The remaining 40% of residential customers use some 70% of the residential total. This modification could also save considerable administrative time.

A new classification of "institutional" was suggested for schools, churches, hospitals, and government services with a 20% reduction requirement.

Rather than a flat penalty system, a graduated one was recommended. Moreover, it was felt that the average of two months' bills should be used for penalty purposes. This avoids problems with occasional meter estimation and other minor irregularities. The option of being able to "work off" a penalty by decreased use in the following month was suggested.

Despite the reduction in usage, citizens made it clear by a deluge of inquiries and complaints that they did not understand the adequacy of their efforts at compliance. The efficacy of various conservation strategies was unknown and people generally were unable to read their meters. It became evident that the administrative machinery for the task of informing the people, implementing the ordinance, equitably enforcing the penalty program and associated provisions did not exist. Thus, penalties were suspended on January 25 until after March 31, 1974 when adequate administrative mechanisms could be set up.

It is interesting to note that subsequent to the program, Los Angeles residents continued to conserve at a rate of about 12%. This created a difficult situation for the Department of Water and Power as lessened usage places upward pressure on rates.

In the Los Angeles experience, it is important to note that the municipal utility is a department of city government. As such, alternatives were available to the Mayor and City Council which would not be available to the Metropolitan Government of Nashville-Davidson County in a similar situation; the Nashville Electric Service (NES) - through the Electric Power Board - is insulated from direct political control by municipal government.[8]

3. METROPOLITAN NASHVILLE - DAVIDSON COUNTY

3.1 INTRODUCTION

The city of Nashville and Davidson County, united in 1963 under a mayor-council form of government, lie in the northern center of the state of Tennessee on the Cumberland River. In 1974, the Metropolitan area proper, the primary focus of this study, had an estimated population of 469,500. However, the SMSA estimate was 750,000, and the Retail Trade Zone contained approximately 1,271,400 people.

Metro Nashville is a focal point of Southern life. It is a regional center of industry, finance, education, recreation and product distribution - located at the intersection of Interstates 40, 24 and 65, as well as two railroads. Its industry is chiefly devoted to production of consumer goods, notably shoes, paper products, hosiery, stoves, food products, glass, appliances, synthetic fibers, barges, boats, tires and resins. Printing and music are also major contributors to the Nashville economy.

Nashville is a major retail-trade center, with a central-city shopping area and twenty-seven major retail-sales centers located elsewhere. There are an estimated 232,362 households in Metro, with a total personal income last year of $3,291,420,000 ($14,165/household). Of that total income, approximately $1,288,744,000 (39%) was expended in the retail-sales market.

Excepting perhaps iron and steel based manufacturing, Metro Nashville has a diversified economy, with substantial dependence on industry and commerce, in both goods and services, as well as transportation. Agriculture, as well, centers around Nashville. In the SMSA there are approximately 13,796 farms, which brought to the markets last year $19,667,000 in crops, and $61,576,000 in livestock. This sort of diversity makes Nashville an ideal laboratory in many respects for our purposes.

3.2 POLITICAL - LEGAL ASPECTS OF THE POWER SUPPLY SYSTEM

The power supply and distribution system for Metro has some unique characteristics, which must be taken into account.[8-10]

Nashville's electric power is generated by the Tennessee Valley Authority (TVA), the world's largest single producer of electricity. TVA, established by Congress in 1933, is a public corporation, governed by a three-man board of directors appointed for nine-year terms by the President, with the advice and consent of the Senate.[11] It receives Congressional appropriations each year for its non-power programs, but its power program must generate sufficient revenue to cover its costs and make in-lieu-of-tax payments back to the Treasury.

Thus, TVA differs from a private utility in that it serves a larger region, most of the area of which is non-urban agricultural land, and it is more directly subject to Congressional pressure (a factor somewhat mitigated by TVA's complete freedom from regulation by the Federal Power Commission and all state and local regulatory bodies). The General Accounting Office and the Environmental Protection Agency serve as significant controlling agencies, if indirectly. Essentially, TVA is indirectly affected by federal decision-making as though it were a private corporation of equivalent size and interests.

TVA sells its power to more than 160 private distributors, ranging in size from tiny rural electric cooperatives to large urban agencies in Memphis, Nashville, etc. The Nashville Electric Service (NES) is the TVA distributor throughout Metro, serving its customers through more than 170,000 meters. NES is a proprietary function of Metropolitan Government; as such it is a quasi-public agency, exempt from regulation by the Tennessee Public Service Commission, but liable to suit by private parties in much the same way as a private utility. The Mayor, subject to the approval of the Metro Council, appoints the five members of the Electric Power Board, who control the affairs of NES with virtual autonomy, a power authorized by the Metropolitan Charter.

In theory, consumer input into these agencies can be achieved through both the legal and political processes. In practice, local control has been minimal, although policies have recently been altered by both TVA and NES under threat of class-action suit, as well as through political pressure expressed through Congress. This situation affords certain advantages in terms of centralized regional policy-making and crisis management; however, from Metro Nashville's standpoint, it lessens the control which local political institutions and hence the public can exert - a different situation from Los Angeles, certainly.

3.3 DISTRIBUTION IN DEMAND FOR ELECTRIC POWER[12]

Table I indicates that the time of year at which a crisis occurs may make a significant difference in choosing a strategy for crisis management.

From analysis of this data several points can be made: 1) In the winter months there is a large shift from "base-load use" to higher average consumption* on the part of most residential users. In effect, it is as though 1/2 of the users increased their monthly consumption by 2000 KWH, which is compatible with the fact that 60% of the users have electric heating. In fact, the residential use essentially doubles while the commerical/industrial use is essentially unaffected. (This is further illustrated by Fig. 1.) 2) In the summer months there is an effective increase in monthly use of about 500 KWH on the part of all users.

This indicates that strategies which are designed to limit the maximum consumption of electric power would impact various segments of the user population in different ways, according to the season.

As an aid to designing effective strategies, the consumption is disaggregated into end-use (Figs. 2 & 3) averaged over the year.** It is important to realize that seasonal variations in this disaggregation must be taken into account. For example, strategies designed to reduce peak-load consumption must relate to winter-time usage (Fig. 1), while strategies reducing overall energy consumption must vary seasonally.

It is also interesting to note that because of the nature of use in Nashville-Davidson County (where 50% of the homes are all-electric) any effective strategy must deal with space-heating and air conditioning, which account roughly for 1/3 of the power consumed annually (Fig.3).

3.4 GROWTH OF DEMAND

The use of electric energy in the TVA region has grown rapidly over the past fifteen years. Assessing the potential for future power-supply crises must begin with an understanding of the total power demand, and of the types and generating capacities of the plants which provide their power.

Since 1960 the sale of TVA power has grown at the rate of about 4% per year, and of the total ($\sim 100 \times 10^9$ KWH in 1973) about one third is for residential use, and the remaining two thirds for commercial and industrial use. The mean residential use in the TVA region is about twice the national average of 8000 KWH/yr/dwelling. In the Nashville-Davidson County Metropolitan area, the average use per residential customer was

TABLE I Distribution of Residential Electrical Energy in the NES District for December, May, and August (1973-74)

User Group (KWH/Mo.)	per cent of Total Users	per cent of Resid. Energy	per cent of Total Energy
December (1973)			
A: 0-650	19	2.4	1.3
B: 651-1250	14	5.4	3.0
C: 1251-2000	13	8.2	4.5
D: 2000-4000	34	40	22
E: >4000	20	44	24
May (1974)			
A	30	10	3.8
B	35	32	12
C	26	38	14
D	8	19	7
E	0.3	1.6	0.6
August (1974)			
A	21	4.4	2.1
B	24	15	7.1
C	28	29	14
D	25	44	21
E	2.2	7.5	3.6

*Consumption in May, at which time heating and air conditioning should be minimal, is used as an indication of "base-load" use.

**Information on the disaggregation of this power by end-use is available for the residential sector in a TVA marketing analysis for Nashville,[10] but the commercial and industrial sector figures are national averages excerpted from a Federal Power Commission National Power Survey.[13]

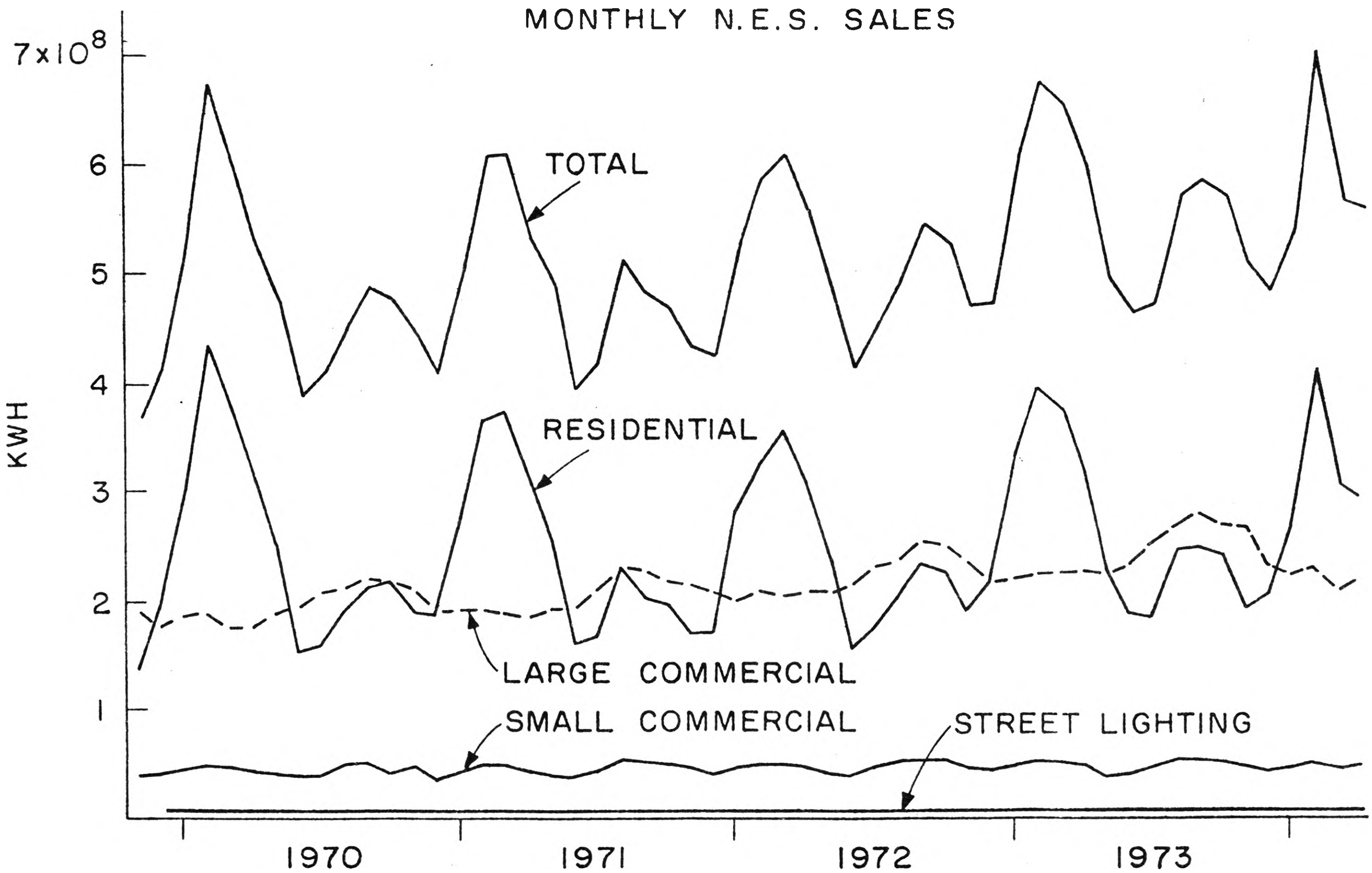


FIG. I MONTHLY SALES IN THE N.E.S. DISTRICT

more than twice the national average or approximately 20,000 KWH/yr. As noted previously, 50% of NES living units are all-electric.

This rising demand is a consequence of two multiplicative factors: an increasing number of customers and an increase in their average use rate (KWH/yr). This demand is cyclic, with both daily and seasonal variations. Characteristically, during the day the demand starts rising above the average at 7:00 A.M. reaching a plateau at 8:00 A.M. which gradually peaks at about 6-9 P.M., depending upon the season, then dropping to the average two hours later, with correspondingly lower use during the night. The rise above the average is usually about 12%. This daily cycle is superimposed upon a seasonal variation (Fig. 1.) which reflects the heating and cooling demand of winter and summer. These seasonal variations for residential demand are very large, involving a 100% rise over the base-line use. For example, in October of 1973 the residential demand from NES was a little less than 200×10^6 KWH/month, while in January 1974, three months later, it was a little more than 400×10^6 KWH/month.

3.5 TECHNICAL ASPECTS OF THE POWER-SUPPLY SYSTEM[10,14]

In addition to providing power to Nashville, TVA supplies most of the Southeastern United States with power generated from a mix of hydroelectric generators (21%), coal-fired steam turbines (78%), and nuclear reactors (1%). Peaking power also is supplied by small gas-turbine units and some pumped-storage hydropower.

The capacity of the TVA system must be large enough to accommodate those peak loads accompanying high average demands, even though the daily average power demand is somewhat lower and the monthly and yearly average power demands are very much lower. In fact, the yearly peak demands (winter) in the TVA system exceed its dependable capacity (17×10^6 KW in 1973) by about 10%, but this is accommodated by exchange of

FIG. 2

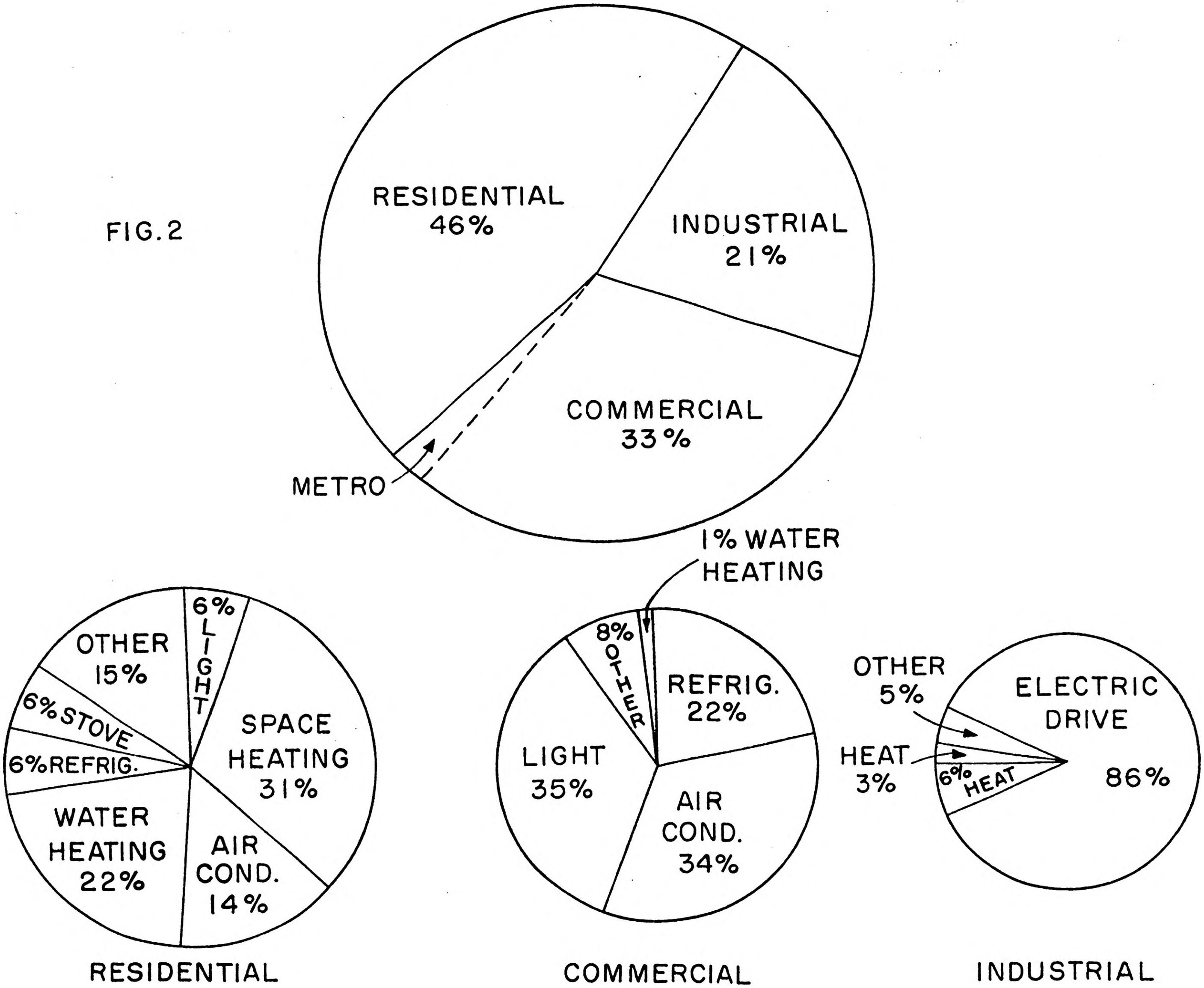
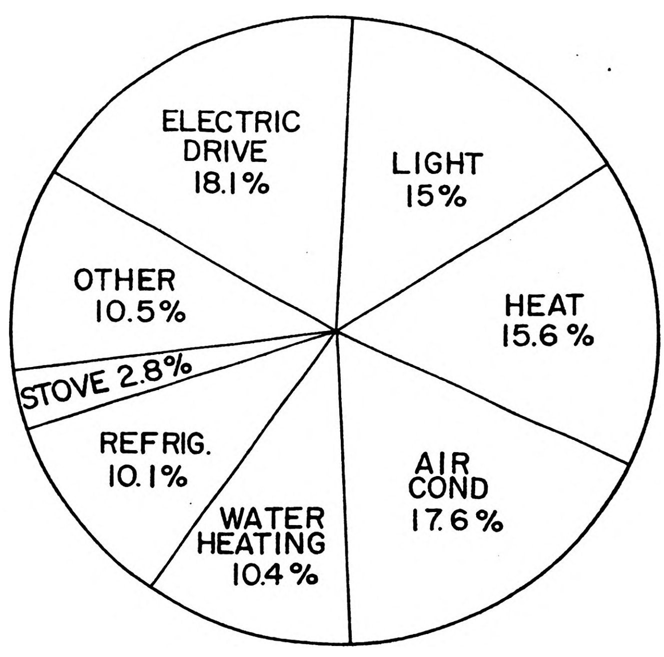


FIG. 3



FIGS. 2 & 3 DISTRIBUTION OF POWER BY-SECTORS AND END-USE IN THE NASHVILLE ELECTRIC SERVICE (AVERAGED OVER 1973-74) power with other systems to the south and west, who in turn draw on TVA capacity during their (summer) peak demands. The installed capacity is about 20% higher than its dependable capacity. This is to be expected, because hydrogenerators cannot be counted on for capacity generation at all times due to climatic conditions, some plants being on a stand-by basis, the occurrence of breakdowns, needed maintenance time, etc. Some improvement in efficiency can be obtained if the load factor (the ratio of average load over some representative interval of time to the peak load occurring in that interval) is maximized. Such "peak-smoothing" in the NES load would result in about a 10% saving since extra coal would not have to be used to provide for peaks.

Because hydrogenerators can be brought on and taken off line in minutes, the practice has been to use hydropower to supply the peak overloads while using the steam plants, which have more inertia, to provide the base loads. Since the possible future sites for hydroelectric dams are few, the growth in the demand for power is pushing the limits of flexibility offered by this approach. It is intended that nuclear power generators take over their function since they can respond more quickly to demand. When Browns Ferry units #1, 2, and 3 are fully operative, the complex will exceed in capacity the total output of all TVA hydrogenerators. In fact, projected nuclear capacity will increase the total TVA capacity by 50% some time after 1980.

3.6 PRESENT AND FUTURE NEED FOR REDUCTION

Because of potential coal supply shortfalls arising from the demands of organized labor and uncertainty over future strip-mining regulations (and also because of difficulties in increasing nuclear capacity on schedule) some pressure exists to decrease total power demand. If economy measures reduced the demand by 20%, this would be a one-step process, and the continuing growth in use and users would bring us back to the same level of demand in the TVA region in less than four years. This could only be prevented or delayed if the average demand (KWH/customer) were stabilized (likely) and if the growth in the number of customers were stabilized (unlikely).

Using NES as a representative sample, the demand of the residential sector seems to be growing at a rate of 1.3% per year, while that of the commercial-industrial sector is much higher at 6.5% per year, giving a growth in the total NES system of roughly 4%/yr. A contributory factor to the growth in residential demand for power, aside from the growing population, is the increase in the use of electric appliances. In 1973, 64% of the residential users had washing machines, 30% had freezers, 47% had clothes dryers, and 25 % had dishwashers. These units use about 6 % of the total energy consumed, and it is estimated that growth toward saturation (more users) would raise this to only 6.6% in 1983. A more likely cause for the growth in demand would involve refrigerators (99% saturation in 1973 but showing a 4%/yr rise in power requirements), air conditioning (82% saturation in 1973) and electric heating (58% saturation in 1973 expecting to rise less than 1%/yr), all of which use up over 50% of the power demanded by residents. Little change in this 50% factor is expected. However, the number of users is expected to increase 30% in ten years; this is the main cause for the expected increase in power demand.

In other use sectors, street lighting comprises less than 0.5% of the use, and strategies involving reduced street lighting would be essentially ineffective except for its psychological value, and the negative impacts on crime and safety could outweigh this. In the residential sector, lighting comprises only 6% of the total residential power used. On the other hand, lighting in the commercial and industrial sectors in some cases comprises the major fraction of their power demand. Since these sectors comprise 54% of the NES load and 75% of the TVA load, this provides for opportunities to effect a major reduction in power demand.

A voluntary reduction in lighting use by 50% and in heating by 30% (a ten-degree lowering of the thermostats and an approximate 3% reduction in heating power per degree lowered) would result in an overall reduction in the NES district by 12 percent. This assumes total compliance by the consumers and negligible chances of voluntary saving elsewhere. It appears unrealistic to expect 100% compliance; thus, the record of other regions (see Sections 2.1-2.3) which indicate a 6-10% reduction in power use by voluntary curtailment is likely to be repeated in the NES district.

If reductions greater than 6-10% in power use are required, other-than-voluntary strategies must be implemented, and their impacts on the various consumers should be considered.

4. THE IMPACTS AND EFFECTIVENESS OF SELECTED STRATEGIES*

Having briefly examined the history of electrical power supply crises and related it to the unique characteristics of the Nashville area, we are now able to draw upon that experience and additional current research to assess the effectiveness and potential impacts of some alternative strategies.

4.1 THE STRATEGIES

The case examples of electric power reduction strategies described in the previous section and in other literature available to the task group (e.g., drafts of TVA and NES power allocation plans) may be classed into three general categories:

I. Voluntary Conservation Appeal: designed to convince the consumers that they can and should reduce their electrical usage. There are no direct sanctions for noncompliance. The overall reduction to be expected from this approach ranges between 5% and 10%.

II. Price Regulation: designed to curb usage and effect a rationing by making the commodity (electrical energy) more expensive. Depending on the particular pricing regulation strategy employed, overall reductions in the range of 10% to 50% may be realized. Extreme pricing rapidly shifts this from a near-voluntary to a mandatory type of regulation.

III. Mandatory Regulation: designed to curtail the use of electrical energy through legislative enactment containing penalty provisions. This category will generally effect the greatest reduction in overall usage, but with a high probability of severe consumer impact.

The task group studied and debated a wide range of possible strategies that could be used to curtail electrical power usage. For the purposes of this preliminary investigation, similar strategies were grouped together and the number condensed until a list of seven separate strategies was identified.

Table II lists these strategies under their general category headings and describes some of the essential features of each. The numerical values shown in the Table for KWH base line usage, percentage rate increases, percentage surcharge, etc. were chosen as being reasonable for the particular residential user patterns, socio-economic data, and industrial manufacturing.

4.2 INTRODUCTION TO IMPACT ANALYSIS

The idea of a technology assessment on a problem of this type is to carefully and systematically look at the strategies that might be adopted to effect certain necessitated goals, and to see what their impact might be on the various groups and institutions within the region. The word "impact" is used here to mean those negative consequences which would be expected to accrue if a particular strategy were to be imposed - not the effectiveness of the particular strategy in reducing electrical-power usage. Once the probable impacts have been assessed, then the idea is, of course, to choose that strategy or combination of strategies which best meet the necessitated goals while placing as little hardship as possible on the people and institutions affected. Only by studying the probable effect of each strategy in turn on each subgroup of the consumer sector can we be sure of not overlooking a possible severe consequence in adopting a particular strategy. Even if we are forced into using a particular strategy, we will at least know beforehand who the most heavily impacted parties are likely to be, and we can begin to take steps to ameliorate the action of this strategy.

A simple method for making this systematic study is to set up a matrix with the strategies that might be adopted listed along one side and the parties (consumers) that might be affected along the other. (See Table VII, the master impact matrix for this study.) Each cell in this matrix represents the interaction of a particular strategy with a particular subgroup of the consumer sector. Then, after careful study, a notation representing the suspected magnitude or level of the impact can be

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*In this section frequent reference is made to the activities of the "task group" in evaluating impacts of alternative strategies. The members of the task group are identified earlier in this paper in Section 1.

TABLE II Essential Features of Electrical Power Reduction Strategies

General Category	Strategy	Description
I. Voluntary Conservation Appeal	A. Media-Intensive Campaign	T.V. and radio spot advertising, newspaper advertising, billboards, pamphlets, and other mass-media efforts.
	B. Personnel-Intensive Campaign	Conservation advisory teams (staffed by TVA, NES, Metro, etc.) working with community groups, schools, churches, businesses, and industrial firms through workshops, seminars, public discussion groups, etc.
II. Price Regulation	A. Surcharge	A percentage of total monthly bill (eg., 50%) would be added to all KWH usage above a certain baseline level. Baseline could be a given monthly level (eg., 650 KWH/mo) or a percentage of previous year's usage by consumer (eg., 80%).
	B. Rate Increase	The cost per KWH would increase with the amount used above a certain baseline level. Prices would begin their progressive increase above a given monthly level (eg., 650 KWH/mo) or above a percentage of previous year's use.
III. Mandatory Regulations	A. Voltage Reduction	A voltage reduction of 5% to 8% would be made on all consumer sectors. Critical customers could petition for full line voltage.
	B. Mandatory Curtailment	1. Winter cut - all consumers would be required by law to use a certain percentage less (eg., 20%) than previous year. 2. Summer cut - same as above. Enforcement penalties: 1st violation - 50% surcharge; 2nd, etc. - 1 to 3 day interruptions.
	C. Power Rotation	Primary substations or distribution lines would be cycled on and off for specified time intervals (eg., 2 hrs). Certain critical loads would remain on.

entered in each cell of the matrix.* For the purposes of this preliminary investigation, the qualitative notations of H (= high impact), M (= medium impact) and L (= low impact) were used. With further investigation, this qualitative scale may be replaced with a quantitative scale of numeric values that will allow summation to show the total impact of a given strategy and better facilitate the ranking of strategies according to their expected impacts. Hopefully, this simple analysis will indicate which strategy or combination of strategies will best solve the problem with the least negative effect.

4.3 CONSUMER SECTOR BREAKDOWN

In order to carry out the exercise described in Section 4.2, the various consuming groups must be carefully identified. The consumer sector for electrical energy usage can logically be broken down into three major groups: residential users, commercial users, and industrial users. However, a study of this type would be of little value if the consumer sectors were left in such an aggregated form.** A

*The task group divided into three smaller groups (of three or four members each) corresponding to the three categories of consumer usage: residential, commercial, and industrial. The groups continued to meet separately for several sessions to go through each cell in each sub-matrix for each strategy in turn. The process required considerable discussion and reference to collected data, until a suitable scenario was generated for each interaction and a rating notation agreed on by the group. The groups quite often kept notes during this process in order to make clear their rationale for choosing certain rating values. At the end of this process, the small groups came together again to discuss their work and record their rating notations on the master matrix form (See Table VII).

**It is desirable to further subdivide the three major user sectors (residential, commercial, and industrial) according to their social and economic characteristics. Within each sector there exist definable groups of users who will react differently to various strategies. Basic data is obtainable from U.S. Census compilations of population, housing, manufacturing, and business data, reports of the Metropolitan Planning Commission, data developed by the Mid-Cumberland Regional Development District staff, sample billing records of the Nashville Electric Service, and energy-use figures from both TVA and NES.

particular power reduction strategy could have widely different consequences in the residential sector, for instance, depending on the income level of the residential users. Another important factor would be the type of dwelling structure in which the user lived, since the electrical power needs of single dwelling units may vary considerably from multiple dwelling apartments. Therefore, if only these two factors are to be considered in the residential user case, we have already defined a sub-matrix of dwelling type vs. income level on top of which we are to consider the impact of each strategy we have designated. An example of the residential sector submatrix we have developed is shown in Table III. This residential submatrix was used to characterize eight user sub-sectors. Effects of all seven strategies were evaluated in turn on each sub-sector. Our analysis of NES residential usage patterns showed that single family dwellings and up to four-unit complexes were very similar; the real differences in usage were between the large apartment complexes and the small complexes of one to four units.

In like manner, the commercial sector was broken down into public and private institutions, with the main differentiation being between offices, stores, restaurants, educational, religious, medical, and government institutions. This commercial submatrix (Table IV) was used to characterize sixteen user subsectors, including stores, restaurants, offices, institutions (educational, religious, medical) and government services. Effects of all seven strategies were evaluated in turn on each subsector.

The industrial sector proved a little more difficult to disaggregate into its most important components. Since this study is concerned with the reduction of electrical energy usage, we felt it desirable to have one classification factor that expressed electrical energy usage directly. Our data allowed us to classify industries in the NES region according to their electrical energy intensiveness: KWH per dollar of value added by their industrial processing operation. Table V is a partial list of area industries classified by S.I.C. code and energy intensiveness. The impact of a particular reduction strategy will be quite different for high energy intensive industries (SIC 22, 26,28,32) than for those which are not (SIC 25,34, 35,etc.). The other important factor for the industrial sector is the size of the firm, and we considered size from both the employment viewpoint and the economic (dollars-of-value-added) viewpoint. These industrial submatrices (Table VI) were used to characterize nine user subsectors according to (1) size of firm (based on value added and on number

TABLE IV Commercial Impact Areas

	PUBLIC	PRIVATE	
		Large	Small
I. Institutions			
A. Education/ Religion			
B. Medical			
C. Gov't. Services.			
II. Offices			
III. Stores			
A. Food			
B. Non-food			
IV. Restaurants			

TABLE III Residential Impact Areas

		INCOME LEVEL				
		Fixed	Low	Medium	High	Total Households
DWELLING TYPE	4 or more units	(15,000)	9,028	15,284	6,816	31,128
	1 to 4 units	(62,000)	36,112	61,136	27,264	124,512
	Total Households	(77,000)	45,140	76,420	34,080	155,640

TABLE V Energy Intensiveness of Area Industries (Manufacturing)

SIC CODE	INDUSTRY	ENERGY INTENSIVENESS (KWH/$ value added)
20	Food and Kindred Products	1.006
22	Textile Mill Products	2.550
23	Apparel and Other Fabric Products	.358
24	Lumber and Wood Products	1.603
25	Furniture and Fixtures	.606
26	Paper and Allied Products	5.029
27	Printing and Publishing	.405
28	Chemicals and Allied Products	4.960
30	Rubber and Plastic Products	1.583
32	Stone, Clay and Glass Products	2.497
34	Fabricated Metals	.710
35	Machinery (except electrical)	.619
36	Electrical Machinery and Supplies	.890
37	Transportation Equipment	.836

TABLE VI Industrial Impact Areas

Energy Intensiveness (KWH/$VA)

SIZE OF FIRM (SIC#)-(Value Added, $)

	Low (0-.75)	Medium (.75-2.00)	High (2.00-)
SMALL ($0-35M)	(SIC#34) $34M $34M	(SIC#24) $15M (SIC#36) $32M $47M	(SIC#22) $30M (SIC#26) $14M $44M
MEDIUM ($35-75M)	(SIC#23) $36M (SIC#25) $37M (SIC#35) $37M (SIC#35) $45M $118M	(SIC#30) $42M $42M	
LARGE ($75M+)	(SIC#27) $112M $112M	(SIC#20) $85M (SIC#37) $140M $225M	(SIC#28) $184M (SIC#32) $146M $330M

Energy Intensiveness (KWH/$VA)

SIZE OF FIRM (SIC#)-(Employees, 1000)

	Low (0-.75)	Medium (.75-2.00)	High (2.00-)
SMALL (0-2.0)	(SIC#34) 2.0 (SIC#35) 2.8 4.8	(SIC#24) 1.1 (SIC#30) 2.7 3.8	(SIC#26) 1.6 1.6
MEDIUM (3.0-5.0)	(SIC#25) 3.4 3.4	(SIC#36) 3.4 3.4	(SIC#22) 3.0 (SIC#32) 4.7 7.7
LARGE (5.0 +)	(SIC#23) 5.5 (SIC#27) 9.1 14.6	(SIC#20) 6.4 (SIC#37) 9.5 15.9	(SIC#28) 7.7 7.7

of employers) and according to (2) energy intensiveness (killowatt-hour of energy used per dollar value added to product).

4.4 MASTER IMPACT MATRIX

There are a number of ways that the matrix of impact values (Table VII) can be analyzed in an assessment study. Individual cells where major (H) and considerable (M) consequences are expected to occur should be noted. Then we should begin to integrate these individual instructions into patterns of high impacts within each sector. These clusters indicate whole regions that we would hope to avoid in selecting a strategy sequence to achieve our necessitated goal. In effect, we might visualize the matrix as a topographical map where the H's represent hills and the L's valleys. Our objective would be to traverse this map from one side to the other (i.e., across all sectors) by choosing the easy routes (low road) along certain strategy paths, changing routes (strategies) whenever the need dictates.

4.5 OBSERVATIONS

When viewed across all consumer sectors, the strategies can be ranked according to their expected severity of impact in the following order:

1. Power Rotation...........highly severe
2. Mandatory Curtailment....moderately severe
3. Price Regulation.........somewhat severe

The Voluntary Conservation Strategies remain low in expected impact because people and institutions will not apply them beyond a certain, low-level limit of discomfort and disruption. Likewise, Voltage Reduction will produce little in the way of disruption except in certain technical-machinery and industrial-processing cases.* It is also apparent that these two strategies (Voluntary Conservation and Voltage Reduction) are quite limited in their effectiveness and can produce at most a 10% savings in electrical power usage.

Within a particular strategy, the following observations can be made:

Power Rotation:

- Expected to impact the fixed and low income residences more severely than others because of lack of flexibility in their living style.
- Expected to place a greater burden on the small store and restaurant owners, on small business offices, and on medical institutions.
- Expected to disrupt the small industrial firms and the highly energy-intensive firms most severely.

Mandatory Curtailment:

- Expected to pose severe hardship on the fixed and low income residences because they have less margin for cutting back on electrical usage.
- Expected to produce a high impact on food stores, smaller offices, restaurants, and medical institutions and on government services such as water and sewage treatment, police, etc.
- Expected to disrupt the small and medium sized firms, especially those which are energy intensive.

Price Regulation**:

- With a proper exemption floor, these strategies should have only minor impact on fixed and low income residences.
- Expected to produce severe economic problems for small food stores, small restaurants, and for small, highly energy-intensive industrial firms.

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*Voltage reduction and power rotation strategies which may adversely effect certain machinery and/or processes can generate adverse feedback for utilities in the form of suits for damage caused by the selected strategy. In cases where insufficient warning has been given of such changes in the power supply, courts have held utilities liable for equipment damage and punitive damages.

**An important area for study is the question of the effect of price on electrical energy use. Recent studies at Oak Ridge National Laboratory(15) indicated the following "elasticity figures" (percent decrease in use for a one percent increase in price):

Residential:	0.4% decrease
Commercial:	1.1% decrease
Industrial:	1.2% decrease

Although these results are from relatively "short term" studies of the TVA region where price increases have been occuring over the past several years, there is considerable uncertainty as to the applicability of these numbers for the "very short term," such as would apply to a quasi-crisis situation. Such very short-term price elasticity data would be most useful in more precisely determining the effectiveness of price restructuring (in bringing about immediate reduction in electrical energy usage). Nevertheless, in the present assessment we are primarily concerned with impacts of alternative strategies on users, and therefore we have included evaluation of the consequences to users of such price restructuring strategies.

TABLE VII Master Impact Matrix

CONSUMER SECTORS

STRATEGIES	RESIDENTIAL								COMMERCIAL																	INDUSTRIAL								
	1 to 4 Units				5 + Units				Stores				Res-tau-rants		Offices			Institutions								Large			Medium			Small		
									Food		Non-Food					Pri-vate		Educ./Relig.			Medical													
	Fixed	Low	Medium	High	Fixed	Low	Medium	High	Small	Large	Small	Large	Small	Large	Public	Large	Small	Public	Large	Small	Public	Large	Small	Government Services	Low	Medium	High	Low	Medium	High	Low	Medium	High
Media-Intensive Campaign	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Personnel-Intensive Camp.	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Surcharge	L	M	M	M	L	L	M	M	H	M	M	M	H	M	L	L	L	L	M	M	M	M	M	M	L	M	M	M	M	M	M	M	H
Rate Increase	L	M	M	M	L	L	M	M	H	M	M	M	H	M	L	L	L	L	M	M	M	M	M	M	L	M	M	M	M	M	M	M	H
Voltage Reduction	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Mandatory Curtailment (1)	H	H	M	M	H	H	M	M	H	H	M	M	H	M	M	M	H	M	M	H	M	M	H	H	M	M	H	M	H	H	H	H	H
Mandatory Curtailment (2)	M	M	M	M	H	H	M	M	H	H	M	M	H	M	L	M	M	M	M	M	M	M	H	H	M	M	H	M	H	H	H	H	H
Power Rotation	H	H	M	M	H	H	M	M	H	M	H	M	H	M	M	M	H	M	M	M	H	H	H	H	M	H	H	M	H	H	H	H	H

KEY: ■ = High Impact, ▨ = Medium Impact, □ = Low Impact

4.6 FACILITATING PUBLIC INVOLVEMENT

An important goal underlying the present study was to address the question of what constitutes the proper and necessary role of "the public" in deciding among alternative strategies for planned reduction of electrical energy. By implication, the broader question of public participation in technological decision-making is being raised as well. In the present study, the student-faculty team (the task group) joined by representatives of the oversight committee acted as surrogate for all publics in determining - with informed subjectivity - the relative impacts of the alternatives. Although certain kinds of expertise were present in the task group, and despite the obvious lack of representatives from many user subgroups, the "model" of the task group and oversight committee was more representative of a public equipping itself to make an important decision than of an insulated body of technical and bureaucratic expertise. The team gathered the information, consulted the experts when necessary, analyzed data and developed a methodology for choosing among alternatives. During this process, the group underwent a mutually self-educating experience as to the total problem perspective. This was as true for participating representatives from NES and TVA - functioning out of their customary environment of "institutional expertise" - as it was for students and faculty. That the information developed in this assessment was "useful" is attested to by the fact that several members of the task force served as advisors to the Mayor's office during the crisis period, previous to and during the UMW coal strike affecting TVA in November of 1974. The policy statement issued by the Mayor's office during this period utilized many of the results of this study.

One therefore wonders if this "model" of problem-oriented technology assessment may be extended to the community at large (or, what is more likely, to identifiable subgroups of the community) who can provide valuable input to the decision-making process. Furthermore, can the university with its multiplicity of resources (including students and faculty) serve as the convenor in such crisis-averting or crisis-moderating exercises? Traditionally the community entrusts the tasks of providing public technical services (utilities, communication, water supply, sanitation, refuse disposal) to a properly constituted, technical authority. The expectations are clearly that expertise will prevail, including planning for unusual and unexpected occurrences. As pointed out in Section 3.2, insulation from public involvement is assured by statute in the case of TVA/NES. In this and in similar cases, the law must be assumed to reflect the general public attitude of "let the expert do it." But that attitude is changing (Section 3.2) reflecting greater social complexity of technical decisions and the consequent demand for public involvement and accountability. It is within this context of increased public awareness and community need that the university is challenged to expand its traditional educational role of professional career preparation and/or liberal, general education. The details of organization and cost-effectiveness are well beyond the scope of this paper.

We would hardly suggest that such a proposed model is without ambiguity. The timing of such university-convened and community-participating assessments in relation to emerging or suspected "crises" is critical. How is it possible to sustain the interests of publics in the absence of the crisis? How can one deal with the problem of conflicting crises such as public concern with environmental issues undercut by concern with energy shortages? How can public inputs be effective when the crisis is fast upon us, and experts must make choices without delay? But "leaving it to the experts" is notwithstanding the more dangerous option as the following frequently-cited caveat attests:

> "It is one thing to urge the need for expert consultation at every stage in making policy; it is another thing, and a very different thing, to insist that the expert's judgment must be final. For special knowledge and the highly trained mind produce their own limitations which, in the realm of statesmanship, are of decisive importance. Expertise, it may be argued, sacrifices the insight of common sense to intensity of experience. It breeds an inability to accept new views from the very depth of its preoccupation with its own conclusions. It too often fails to see round its subject. It sees its results out of perspective by making them the centre of relevance to which all other results must be related. Too often, also, it lacks humility; and this breeds in its possessors a failure in proportion which makes them fail to see the obvious which is before their very noses. It has also a certain caste spirit about it, so that experts tend to neglect all evidence which does not come from those who belong to their own

ranks. Above all, perhaps, and this most urgently where human problems are concerned, the expert fails to see that every judgment he makes not purely factual in nature brings with it a scheme of values which has no special validity about it. He tends to confuse the importance of his facts with the importance of what he proposes to do about them."*

5. CONCLUSIONS AND RECOMMENDATIONS

This study sought systematically to pursue the consequences (technological, economic, social, and political) of strategies designed to reduce electrical energy consumption, given the need for such reduction. The study has succeeded in identifying subclasses of users and reduction strategies and has applied one particular assessment methodology in reaching the conclusions stated in the previous section. An important aid to public-policy formulation would result from the extension of the methodology to involve directly the various affected publics (identifiable groups of residential users in civic organizations, churches, neighborhood community organizations, etc.; Chamber of Commerce, businessmen's associations, trade associations, industrial managers, union representatives, etc.). This would require the development of packaged resource information, and the conducting of workshops to facilitate, to the maximum degree possible, public involvement in the decision-making process.

During the course of our study, (June-December, 1974), public-policy decisions regarding total energy use reduction were being formulated at various governmental and quasi-governmental levels in the TVA region: at the local (Metro-Nashville and the NES), the state (Governor's office of the State of Tennessee), and federal (the TVA itself). The threat of an impending coal strike in August and its brief realization in November of 1974 produced a "crisis" situation which enhanced the value of our effort in the eyes of local officials. Our preliminary assessment, undertaken, as it were, by an independent group, provided useful inputs for the decisions. These inputs were manifested by involvement of members of the task group in various community task forces, appearances on local public information programs, and through dissemination of a formal report.

Nevertheless, it is clear that despite the substantial accumulation and analysis of information there is a need for more data in order to avoid policy decisions which are unnecessarily socially destructive, or which in fact are "counterintuitive" in their effects.** In particular, in order to assess price restructuring or mandatory reduction strategies more completely, it is necessary to know the relationship between income, living standard, and energy consumption in the residential sector. A detailed analysis of billing data correlated with census-tract data is essential. Although we may presume a general correlation between income and electrical-energy use, the quantitative details have a number of implications for policy planning. Not the least of these are guidelines for setting threshholds or lower limits of energy use in price restructuring or mandatory strategies.[16]

Analysis of the political-legal aspects of the power supply system revealed the extent of insulation from direct public accountability which is afforded to the TVA and NES by existing statutes and their implementation. Further knowledge of the "micropolitical" details such as the relationships between decision-making groups, the identity of the key actors in the policy-setting and decision-making drama, the precedents of local customs, etc., all would be an important aid in allowing an optimal choice of strategy by an informed public.

Finally, there are additional technical aspects of the strategies associated with planned reduction which have been neglected in this preliminary analysis and which must be considered in further assessments. The need is clear for the development of methods for user control of equipment to bring about both reduction and redistribution (load leveling). In addition there is a need for new methods for direct utility control, whereby selective reduction (comfort heat but not food refrigeration, for example) could be affected. The need for careful assessment of impacts is obvious in these cases.

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*For example see Harvey Brooks in The Government of Science, M.I.T. Press, 1968, pp. 89,90. The original source of the quote is Harold Laski, "The Limitations of the Expert," Fabian Tract Number 235.

**An example of the latter would be voltage reductions (Strategy III A, of Table II) which although of low general impact would be virtually ineffective in reducing fuel consumption.

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7. BIOGRAPHIES

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