Pakistan Journal of Applied Economics, (1990), Vol. IX No. 2 (117 -146)

THE DIFFERENTIAL IMPACT OF POWER LOADSHEDDING ON INDUSTRIAL UNITS IN PAKISTAN

Hafiz A. PASHA, Aisha GHAUS and Salman MALIK*

The objective of this paper is to highlight the fact that power outages in the industrial sector of Pakistan have not only affected the overall level of output and value added but the impact has also been highly differentiated in character. This has meant that the burden of adjustment to the energy shortages has fallen primarily on small and medium-sized firms. It is likely, therefore, that loadshedding will exacerbate the inter-personal distribution of income in the country. As such, policy in the energy sector will, of necessity, also have to incorporate equity considerations.

I. Introduction

The decade of the Eighties witnessed a major increase in the frequency and intensity of power loadshedding in Pakistan generally and in the industrial sector in particular. It is commonly perceived that during the first half of 1989, loadshedding attained peak levels and in the absence of decisions on lumpy power generation investments (like the construction of large dams) the problem will worsen in the future. The Seventh Five Year Plan [Planning Commission, (1988)], clearly recognises the fact that the power shortage has begun to exercise a strong restraining effect both on the level of output[1] and the rate of investment in the

* The authors acknowledge the research funding from the Water and Power Development Authority (WAPDA) and the United States Agency for International Development (USAID) Power Development Program, Rural Electrification Project 391-0473. Thanks are due to Mark Gellerson and Donn Routolo for their valuable advice and comments and to Firasat Ali and Faud Usman for their research and programming assistance. Any defects which remain are, of course, the sole responsibility of the authors.

[1] The industrial sector of Pakistan grew at the rate of 3.1 per cent only in 1988-89, as compared to 10.0 per cent in the previous year. Part of this decline in growth rate can be attributed to the relatively high incidence of loadshedding between December 1988 and June 1989. The most severely hit industries are textiles, vegetable ghee, machinery and equipment, which are especially vulnerable to loadshedding.

economy. Pasha, Ghaus and Malik (1989) quantified the cost of loadshedding in the industrial sector of Pakistan for the year 1984-85.[2] They estimate that this has led to a reduction in value added by this sector of about 6 percent, equivalent to a loss of over Rs.4.5 billion.

The objective of this paper is to highlight the fact that not only has the overall level of output and value added been affected by loadshedding, but the impact has also been highly differentiated in character. This has meant that the burden of adjustment to energy shortage has fallen primarily on small and medium-sized firms. It is likely, therefore, that loadshedding will exacerbate the inter-personal distribution of income in the country.[3] As such, policy in the energy sector will, of necessity, also have to incorporate equity considerations.

The paper is organised as follows: Section II gives reasons for emergence of the power shortage in Pakistan and for the differential incidence of loadshedding. Section III describes the impact of loadshedding on industrial units and gives an overview (details in Appendix I) of the methodology for quantifying the resulting costs. Section IV summarises the principal empirical findings of the study along with the costs of loadshedding in Section V. Section VI presents the national estimates of the costs of loadshedding by size of unit. This is followed by a description of key implications for policy which emerge from the study in Section VII.

II. Causes and Extent of Loadshedding

Causes:

Bulk of the loadshedding[4] in Pakistan tends to be concentrated in winter and early summer months, from December to June. Therefore, the supply-demand imbalance of energy is essentially seasonal in character. This seasonality is accounted for by the fact that hydro-electricity is a major source of power generation in Pakistan. In 1984-85, the year of the study, the share of this source in total installed capacity for generation was 52 per cent.[5] Electricity generation from the two largest dams, Tarbela (1,750 MW) and Mangla (800 MW), varies seasonally because they are oriented towards meeting irrigation requirements at particular times of the year, and also because of the pattern of the filling and

[2] Annual cumulative loadshedding in 1984-85 was as high as 11,335 MW. It ranged from a maximum of 1,800 MW in March 1985 to a minimum of 566 MW in October 1984.

[3] The impact of loadshedding has also been regionally differentiated, with the hardest hit provinces being the Punjab and the N.W.F.P.

[4] Over 80 per cent of the loadshedding tends to be in the second half of a fiscal year.

[5] The current share of hydro-electricity in total installed capacity generated is 40 per cent.

depletion of their reservoirs. The overall consequence is that the Water and Power Development Authority's (WAPDA) hydro-generation capability varies from a low of approximately 1,020 MW to a peak of 2,897 MW.

The relatively high incidence of outages in 1984-85 can be explained by the fact that it was an exceptionally dry year. As a consequence, there were extended periods of time between December 1984 and June 1985 when WAPDA's generating capacity fell down to 2,200-2,600 MW, while the estimated demand was in the range of 3,200-3,800 MW. A similar story has been repeated in 1989 when at its peak, loadshedding of upto 1,900 MW was required.

It is, of course, clear that if there existed a margin of unutilised capacity in other sources i.e., nuclear and thermal, during the period when hydro-electric generation is at its peak, then the excess capacity could be put to use between December and June. However, the rapid growth in demand during the 1980s of about 12 per cent per annum has meant that generation capacity is utilised, more or less, fully throughout the year. This rise in consumption has been caused primarily by the extraordinarily rapid increase of over 16 per cent per annum in domestic energy consumption, which now accounts for almost one-third of total demand. The buoyancy in domestic demand can be attributed, first, to the presence of subsidized tariffs which have declined by 47 per cent in real terms over the decade. Second, there has been a phenomenal increase in the use of electrical appliances like airconditioners, refrigerators, televisions, etc., many of which have been purchased by workers in the Middle East for their families living in Pakistan. Third, the program of rapid village electrification in recent years has added significantly to the number of domestic consumers. The presence of resource constraints has meant that WAPDA's development budgets have not been able to grow fast enough to cater fully for the increased demand.

The future prospects for outages rest crucially on the extent to which the accelerated program for investment and rehabilitation is implemented. The Seventh Five year Plan allocated Rs.131.8 billion (38 per cent of the Plan) for development of the power sector during the period, 1988-89 to 1992-93. It is envisaged that generation capacity will be increased from 6,716 MW to 13,112 MW. However, ADP (Annual Development Programme) allocations to the sector in the first two years of the Plan are operating in the range of 50-60 per cent of the target.

Extent:

The implications of energy shortage in 1984-85 on the incidence of loadshedding in the industrial sector of Pakistan are presented in Table 1. These estimates are based on a survey of 843 units carried out in 1985-86, which is described in detail in a subsequent section.

The table clearly reveals the differential incidence of loadshedding by size of

TABLE 1

Frequency, Duration and Total Incidence of Loadshedding by Size of Unit by Industry Group

(Loadshedding)

Industry Group	Small				Medium				Large			
	No. of Units in Sample	Fre-quency (No.)	Average Duration (Hrs)	Total Hours	No. of Units in Sample	Fre-quency (No.)	Average Duration (Hrs)	Total Hours	No. of Units in Sample	Fre-quency (No.)	Average Duration (Hrs)	Total Hours
Food, Beverages & Tobacco	48	136	1.75	238	60	131	1.43	187	30	146	1.34	196
Textiles	37	116	1.49	173	90	94	2.01	189	81	97	1.27	123
Wearing Apparel & Footwear	7	137	1.35	185	13	20	1.25	25	7	50	1.28	64
Wood & Paper	41	140	1.44	202	10	97	1.21	117	12	72	1.01	73
Chemicals	25	111	1.62	180	32	71	1.66	118	33	15	1.20	18
Non-metallic Mineral Products	14	142	1.65	235	23	65	1.39	74	9	21	1.19	25
Metal & Metal Products	39	149	2.42	302	56	94	2.15	198	22	77	1.62	125
Machinery & Equipment	62	125	1.74	218	46	126	2.13	268	28	49	1.55	76
Other Manufacturing Industries	0	131	1.48	194	8	204	1.09	223	6	88	1.25	110
Sample	**273**	**131**	**1.76**	**230**	**338**	**101**	**1.77**	**179**	**228**	**78**	**1.32**	**103**

unit. The average hours of loadshedding experienced by the sample of small-scale units (employing less than 10 workers) is 230 hours, which is more than twice the average for large-scale units (employing 50 workers or more) at 103 hours. Medium-sized (employment of 10 to 49 workers) units lie between the two extremes, with average loadshedding of 179 hours. Not only is the frequency of loadshedding higher for small-scale units, but the duration each time is also greater.

Table 1 also indicates that the variation in hours of loadshedding across industries is not as pronounced in the case of small-scale units as it is in large-scale units. For example, the latter have been exposed to only marginal loadshedding in industries like chemicals and non-metallic mineral products. In such industries, the ratio of hours of loadshedding between small-scale and large-scale units is as high as 10:1.

The differential incidence of loadshedding can be attributed to a number of factors. First, WAPDA has made a conscious effort to protect large units in continuous process industries[6] like chemicals, non-metallic mineral products, etc., which are especially vulnerable to loadshedding with high likelihood of spoilage of materials in process. Second, it is difficult for the power utility to give special priority to small-scale industrial units, which are frequently located in residential areas and do not have dedicated feeders as may be the case for large manufacturing units, offices, commercial establishments, hospitals, airports, etc. Third, given the economic power of large firms it is possible that they have been successful (with or without commissions) in negotiating with WAPDA a favourable allocation of power during periods of rationing.

III. Methodology of Quantifying Cost of Loadshedding

The simplest approach [Mattson (1968); Telson (1975)] to the estimation of loadshedding costs consists of derivation of energy coefficients [value added per kilowatt hour (KWH)] for each industry.[7] It is assumed that these coefficients represent the unit cost of loadshedding. However, this approach has a number of basic defects. On the one hand, it tends to understate costs because of the exclusion of some costs, especially due to spoilage of materials in process. On the other hand, it may overstate costs in cases where firms are able to recover at least part of the lost output through various adjustment mechanisms.

[6] Continuous-process units in the sample experienced only half the hours of loadshedding faced by batch-making units.

[7] The average value added per KWH for all industries is Rs.11.77, according to the Census of Manufacturing Industries for 1984-85, carried out by the Statistics Division. A similar magnitude is obtained by dividing the value added in the manufacturing sector, as given in the national income accounts, by industrial power consumption reported by the utilities i.e., the WAPDA and the KESC.

The next generation of approaches has been developed by Mattson (1966), Munasinghe and Gellerson (1979) and Sanghvi [(1882); (1983)]. It explicitly recognises the fact that firms are not passive entities dependant upon market conditions, margin of excess capacity, etc., but attempt to recover at least part of the foregone output if the benefits of doing so in terms of higher revenues more than compensates for any adjustment cost. Various types of adjustments have been identified including the more intensive operation of machinery and overtime.

A similar approach has been adopted by us for quantifying the costs of loadshedding. In line with the above, two types of costs are postulated – direct costs and indirect costs. The former consist primarily of spoilage cost and idle factor cost, which is the value of net lost production. The latter constitute the adjustment costs. The particular mechanisms chosen by a firm for recovering output lost will, of course, be based on cost minimisation considerations. Accordingly, firms would opt for a particular strategy upto the point where it is cheaper than other options. As such, indirect costs could include higher wear and tear cost as a result of more intensive operation of machinery, higher labour costs associated with additional overtime or shift differentials and so on.

We have also introduced a particular refinement to the methodology which is essential in the Pakistani context. This extension consist primarily of distinguishing between short-run and long-run adjustments. The latter become relevant when energy consumers develop expectations about the continued prospect of loadshedding in future, as is the case in Pakistan. The consequence of the formation of these expectations is that firms start exploring other mitigating options which are either not feasible in the short run, or are not economically justified if loadshedding is expected to be a temporary phenomenon. Perhaps the best example of a long-run adjustment is the installation of standby self-generation facilities which can be activated during outages. Other possibilities include renegotiation of labour contracts which allow for changes in shift timings or working days during periods when loadshedding is at its peak or investment in modifications of production techniques/processes which reduce vulnerability to outages.

The survey of industrial units has revealed that a significant proportion of units have installed generators or changed shift timings/working days. Consequently, costs of such adjustments have to be quantified. Details of the methodology developed by us for quantifying costs of loadshedding are given in Appendix I.

IV. Results of Empirical Analysis

The primary source of data was a survey with a pre-designed and tested questionnaire of a stratified (by location, industry group and unit size) national random sample of 843 industrial units. Information on the population of industrial units was obtained from the provincial directories of industries prepared by the respective labour departments.[8] The sample has 440 units from the province of Punjab, 335 from Sindh and the rest, 68 from NWFP and Baluchistan. 228 of the sample are large-scale, 338 are medium-scale and the remaining 227 are small-scale units. The sample units have been classified into nine industry groups. As mentioned above, the year chosen for analysis in 1984-85, a year when loadshedding was exceptionally high.

Results of the empirical analysis, particularly in terms of differences by size of unit, are discussed below.

Pattern of Spoilage Costs:

Estimated spoilage costs due to loadshedding of one to two hours duration (the typical duration) as a percentage of the average value of production are presented in Table 2. For five out of nine industry groups, the spoilage cost curve with respect to unit size appears to be inverted U-shaped, with the highest cost being observed for medium-sized units. In the remaining four industry groups, the incidence of spoilage is the highest in small-scale units in food, beverages and tobacco, chemicals and machinery and equipment. By and large, spoilage costs associated with loadshedding appear to be relatively high for small- and medium-scale units.

Pattern of Time and Effective Production Losses:

Time losses which arise from loadshedding include the anticipated closure time plus actual outage time plus restart time. Effective production losses are time losses adjusted for the extent of production that is possible during that stoppage. Tables 3 and 4 give these losses for the typical duration of outages. There appears to be no systematic variation in these losses by unit size.

Types of Adjustments to Outages:

As shown in Table 5, about 80 per cent of the sample units have responded to loadshedding by making some form of adjustment. The table, however, demonstrates that small-scale units have relatively greater difficulty in working their way around outages. 69 per cent have made some adjustment, as compared to 79 percent and 87 per cent in the case of medium-scale and large-scale units respectively.

8 Provincial directories of industries have been used to obtain population of industrial units, first, because these are uptodate and include all the units registered till 1984-85; second, industries are classified at a relatively disaggregated (four digit) level and, finally, since units of all sizes are included unlike the Census of Manufacturing Industries of the Statistics Division, Government of Pakistan, which primarily covers large and medium-scale units.

The most common adjustments by small-scale units are more intensive utilisation of existing capacity before or after the anticipated outage or changes in production techniques to reduce vulnerability to loadshedding. In contrast to this, the most popular adjustments by large-scale units are either additional overtime or purchase of stand-by generators or higher rate of capacity utilisation.

TABLE 2

Magnitude[a] of Spoilage Costs due to Loadshedding
by Size of Unit by Industry Group
(Spoilage costs as a percentage of the average value of production[b]
per hour due to loadshedding of duration of one to two hours[c])

Industry Group	Small	Medium	Large	Total
Food, Beverages & Tobacco	141[d]	24	88	79
Textiles	35	98	6	51
Wearing Apparel & Footwear	9	6	55	19
Wood & Paper	29	67	13	32
Chemicals	55	43	11	34
Non-metallic Mineral Products	0	20	0	10
Metal & Metal Products	37	59	20	44
Machinery & Equipment	137	67	29	91
Other Manufacturing Industries	0	39	0	17
Sample[d]	**74**	**33**	**21**	**54**

[a] Average for units in the sample.

[b] This is the value of production that would have taken place in the absence of loadshedding.

[c] This duration has been chosen because the average duration of loadshedding observed in the sample is 1.67 hours (see Table 1).

[d] Spoilage costs are in excess of 100% because these costs are measured in relation to value of production per hour.

TABLE 3

Extent of Time Losses[a] due to Loadshedding by size of Unit by Industry Group

[Time Loss (hours) due to Loadshedding of Duration one to two hours]

Industry Group	Small	Medium	Large	Total
Food, Beverages & Tobacco	2.73	2.53	3.15	2.74
Textiles	2.14	2.34	1.98	2.17
Wearing Apparel & Footwear	1.69	1.99	2.36	2.01
Wood & Paper	2.00	2.32	2.64	2.36
Chemicals	2.79	2.61	3.00	2.80
Non-metallic Mineral Products	2.40	2.30	2.42	2.36
Metal & Metal Products	3.58	2.59	3.37	3.07
Machinery & Equipment	3.50	2.28	2.47	2.88
Other Manufacturing Industries	1.58	2.30	1.86	1.97
Sample	**2.78**	**2.42**	**2.63**	**2.60**

[a] Time Loss = anticipated closure time + actual outage time + restart time.

TABLE 4

Production Losses due to Loadshedding by Size of Unit by Industry Group

[Production Loss (in equivalent normal production hours) due to Loadshedding of Duration one to two hours]

Industry Group	Small	Medium	Large	Total
Food, Beverages & Tobacco	2.19	2.34	3.09	2.46
Textiles	1.99	2.28	1.94	2.10
Wearing Apparel & Footwear	0.88	1.80	2.16	1.66
Wood & Paper	1.76	2.53	2.46	2.30
Chemicals	2.44	2.39	2.92	2.60
Non-metallic Mineral Products	2.08	2.29	2.23	2.22
Metal & Metal Products	3.30	2.44	3.16	2.87
Machinery & Equipment	2.79	1.93	2.22	2.38
Other Manufacturing Industries	1.78	1.63	1.02	1.55
Sample	**2.37**	**2.25**	**2.41**	**2.36**

TABLE 5

Types of Adjustments to Loadshedding by Size of Units
(percentage)

Type of Adjustment	Small	Medium	Large	Total
Utilising Capacity more Intensively	26	29	22	27
Working Overtime	18	30	31	26
Working Additional Shifts	8	7	6	7
Changing Production Techniques	21	19	11	17
Buying Generators	6	9	22	12
Changing Shift Timings	2	2	0	2
Changing Working Days	2	3	1	2
Making Some Adjustment	**69**	**79**	**87**	**80**

The differences in the overall rate and pattern of adjustment by size of unit highlight clearly the constraints which face small-scale units. First, due to the absence of market power such units cannot generally incur delays in execution of orders. This limits the scope for subsequent recovery of output following loadshedding. Second, given the jack-of-all-trade type of management and the presence of family labour, the scope for increasing working hours through overtime or by operating extra shifts is limited. Liquidity constraints also mitigate against additional wage payments. Third, even though the exposure to loadshedding is substantially greater, few small firms are able to install generators due primarily to shortage of capital to finance the purchase. Fourth, it is possible that there is less access to information on impending outages in the case of small units. Therefore, adjustments cannot be organised in advance. Altogether, the damage inflicted by loadshedding on small-scale units is enhanced by the limited scope for and ability to make adjustments.

Extent of Recovery of Output:

Given the lower rate of adjustment, small firms generally recover a relatively small proportion of the output lost during loadshedding, as shown in Table 6. The highest recovery rate is generally observed in the case of medium-sized units in the sample of 63 per cent, followed by large-scale units at 40 per cent and small-scale units at 35 per cent. In four industry groups highest average recovery rates are observed among large-scale units and in the remaining five groups, among medium-scale units. The higher recovery rate in some industries of medium-sized units may reflect a greater margin of unutilised capacity or greater flexibility in terms of changes in production techniques. For smaller units the generally lower rate is probably due to lower market power and a jack-of-all-trades management and family-based labour.

V. Costs of Loadshedding

Cost Per KWH:

Following the estimation of the total loadshedding cost per KWH not delivered, an aggregate measure of the loadshedding cost per KWH has been derived for each size category in each industry group. This measure corresponds to the weighted average of the outage cost per KWH, where the weight corresponds to the share of each unit in the total quantum of electricity not delivered.

TABLE 6
Extent of Recovery of Output due to Adjustments by
Size of Unit by Industry Group
(Percentage)

Industry Group	Small	Medium	Large	Total
Food, Beverages & Tobacco	44	76	88	82
Textiles	29	31	25	26
Wearing Apparel & Footwear	33	64	90	83
Wood & Paper	28	65	19	29
Chemicals	16	89	19	27
Non-metallic Mineral Products	40	73	84	79
Metal & Metal Products	23	53	18	26
Machinery & Equipment	52	61	78	71
Other Manufacturing Industries	–	65	56	61
Sample	**35**	**63**	**40**	**44**

Weighted average of outage cost per KWH has been estimated as follows:

OC_{ij} = total outage cost incurred by the ith unit in the jth industry;

K_{ij} = normal power consumption in KWH per hour for production purposes by the ith unit in the jth industry;

HRL_{ij} = total hours lost during outages by the ith unit in the jth industry.

Total amount of electricity not delivered, KND_{ij}, is given by:

$$KND_{ij} = K_{ij} \times HRL_{ij}$$

for the industry

$$OCKWH_j = \frac{\sum_{i=1}^{n_j} OC_{ij}}{\sum_{i=1}^{n_j} KND_{ij}}$$

where, $OCKWH_j$ is the outage cost per KWH in the jth industry and n_j is the number of sample units in the jth industry.

Table 7 presents estimated loadshedding cost per KWH not delivered. Given the relatively high level of spoilage cost and low rates of recovery of output, it is not surprising that the cost is generally higher for small-scale units. This is the case in five industry groups – wearing apparel and footwear, wood and paper, chemicals, non-metallic mineral products and machinery and equipment. In two industry groups, viz., food, beverages and tobacco and metal and metal products, the outage cost per KWH is highest for large-scale units and in the remaining two groups, viz., textiles and other manufacturing, in medium-sized units.

It is interesting to note, however, that for the sample as a whole, outage costs per KWH are highest for medium-scale units at Rs.8.11 as compared to Rs.6.90 and Rs.6.03 in the case of small-scale and large-scale units respectively. This is because the former have the highest cost in textiles. This industry also has a share of 53 per cent in the total quantum of electricity not delivered due to loadshedding in the sample.

Pattern of Costs:

Analysis of the components of the outage cost per KWH, in Table 8, shows the relative dominance of direct costs in the case of small-scale units. Again, this is expected because of the relatively low rate of recovery of output by such units.

TABLE 7

Cost of Loadshedding[a] per Kilowatt Hour by size of Unit by Industry Group

(Rupees per KWH)

Industry Group	Small	Medium	Large	Total
Food, Beverages & Tobacco	4.06	2.41	45.71	9.94
Textiles	11.00	17.33	2.99	4.24
Wearing Apparel & Footwear	12.00	7.50	10.40	11.43
Wood & Paper	33.33	17.00	10.25	12.73
Chemicals	17.00	10.21	11.75	10.58
Non-metallic Mineral Products	7.00	4.00	3.80	4.25
Metal & Metal Products	3.58	5.94	19.42	6.52
Machinery & Equipment	71.42	57.00	15.25	25.71
Other Manufacturing Industries	n	7.00	4.75	5.44
Sample	**6.90**	**8.11**	**6.03**	**6.67**

[a] The total average costs of loadshedding are as follows: Small units, Rs.34,000; medium-sized units, Rs.83,000; large units, Rs.190,000.

However, by and large, direct costs account for the bulk of the costs associated with loadshedding. Within these costs, the share of spoilage costs ranges from 69 per cent to 94 per cent and that of idle factor costs from 6 per cent to 31 per cent.

Costs of Self-Generation:

Table 5 has highlighted the fact that by 1984-85, almost 12 per cent of the units in the sample had invested in generators. This proportion was, of course, much higher at 22 per cent for large-scale units and only 6 per cent and 9 per cent for small- and medium-scale units respectively. It is important to see how high costs of self-generation are in relation, say, to the marginal costs of power generation and distribution by the public utility and to the costs incurred due to loadshedding. Therefore, the cost per KWH of stand-by generators installed by industry has been estimated from the sample data and given in Table 9. These range from Rs.1.29 to Rs.7.70 per KWH in the case of small-scale units as compared to Rs.1.87 to Rs.19.61 per KWH for large-scale units. Despite the presence of large economies of scale in the capital costs of generators, it is of significance to note that generally costs are lower for small-scale units in any industry group. This highlights the fact that,

TABLE 8

Components of Loadshedding Costs by Size of Unit by Industry Group

(Percentage)

Industry Group	Small			Medium			Large		
	Direct[a] Costs	Adjust-ment Costs[b]	Total	Direct Costs	Adjust-ment Costs	Total	Direct Costs	Adjust-ment Costs	Total
Food, Beverages & Tobacco	96	4	100	84	16	100	93	7	100
Textiles	91	9	100	93	7	100	94	6	100
Wearing Apparel & Footwear	92	8	100	10	90	100	22	78	100
Wood & Paper	92	8	100	56	44	100	98	2	100
Chemicals	96	4	100	94	6	100	96	4	100
Non-metallic Mineral Products	65	35	100	47	53	100	47	53	100
Metal & Metal Products	96	4	100	94	6	100	89	11	100
Machinery & Equipment	95	5	100	90	10	100	14	86	100
Other Manufac-turing Industries	n	n	n	99	1	100	77	23	100
Sample	**94**	**6**	**100**	**90**	**10**	**100**	**86**	**14**	**100**

[a] Direct costs consist of spoilage and net idle factor costs.

[b] Adjustment costs consist of the following: Labour-related costs, costs of overtime plus additional shifts *plus* capital-related costs: costs of more intensive operations of machinery plus generators *plus* timing-related costs: costs of changing timings of shifts and working days.

TABLE 9

Use of Generators, Extent of Substitution of WAPDA and Cost per KWH

Industry Group	% of Units Using Generators			Extent of Substitution of WAPDA (%)			Cost per KWH of Generators (Rs.)		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Food, Beverages & Tobacco	4	7	20	100	56	77	7.70	15.91	2.04
Textiles	8	7	10	100	100	61	4.63	3.02	2.58
Wearing Apparel & Footwear	14	8	42	69	100	84	2.40	5.11	8.89
Wood & Paper	5	10	8	100	100	74	1.54	37.56	19.61
Chemicals	0	16	30	N.A.	70	76	N.A.	11.75	4.64
Non-metallic Mineral Products	0	9	22	N.A.	96	100	N.A.	1.39	2.90
Metal & Metal Products	5	5	23	60	86	100	1.29	5.97	1.87
Machinery & Equipment	11	15	43	90	68	93	6.10	21.08	6.34
Other Manufacturing Industries	0	25	33	N.A.	77	73	N.A.	32.96	8.75
Sample	**6**	**9**	**22**	**89**	**82**	**82**	**4.35**	**7.91**	**3.34**

because of the differential incidence of loadshedding, it is more economical for smaller industrial units to install generators as they are likely to be utilised more frequently, thereby reducing the annual capital cost per KWH. The higher cost per KWH of generators in medium sized units can be attributed to the fact that economies of scale in relation to small units are more than compensated for by the lower period of outages.

Further, a comparison of the cost per KWH of generators and of loadshedding indicates that for all firm sizes and in most industries, the latter exceeds the former. Prima facie, if loadshedding exists, then this establishes a strong case for investment by industry in self-generation facilities. Profitability of this investment is potentially the highest for small-scale units given that loadshedding costs are generally higher while generation costs are generally lower. However, the fact that the installation rate has been the lowest for such units clearly demonstrates the severe capital constraint with which they are confronted.

An analysis has been undertaken (details in Appendix II) of the period required for investment in generators to pay for itself. For small units in the different industries, this ranges from three to seven years. Therefore, given that lumpy investments like the Kalabagh Dam are not likely to come on line before the year 2000, it appears to be a sensible policy to encourage the development of self-generation capacity by industry in the intervening period.

VI. National Impact of Loadshedding

Following the estimation of loadshedding costs per KWH and given the incidence of loadshedding and levels of power consumption, we are now in a position to estimate the impact of outages in the industrial sector on value added and profitability. If the sample is adjusted to reflect the underlying population distribution of units by industry group, region and size, it also becomes possible to quantify the national impact of loadshedding, and to highlight the differential nature of this impact.

Table 10 gives these estimates for 1984-85. The differential impact is clearly revealed. Loadshedding has reduced value added of large-scale units by about 2 per cent only as compared to 14 per cent in the case of small units and 17 per cent in medium-sized units. Similarly, the reduction in profitability is 9 per cent for large-sized units and as much as 23 and 29 per cent in the case of small and medium-sized units respectively. It is not surprising, therefore, that as a consequence of loadshedding, smaller units have scaled down their investment plans by 33 to 39 per cent as compared to 20 per cent in the case of large-scale units.

Industries where the differential impact is particularly pronounced are textiles, chemicals, metal and metal products and machinery and equipment. Altogether, it is estimated that the reduction in value added due to loadshedding is Rs.2.5 billion

TABLE 10

Impact of Loadshedding on Value Added, Gross Profitability and Planned Investment by Size of Unit by Industry Group

(Percentage)

	Impact on Value-Added[a]			Impact on Gross Profitability			Impact on Investment[c]		
Industry Group	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Food, Beverages & Tobacco	25	5	14	35	13	28	36	35	20
Textiles	6	23	4	10	49	8	27	34	18
Wearing Apparel & Footwear	7	1	4	10	7	3	21	15	18
Wood & Paper	7	3	3	11	7	10	35	30	24
Chemicals	14	23	1	29	38	4	26	44	20
Non-metallic Mineral Products	9	3	1	22	6	1	14	8	6
Metal Metal Products	17	17	1	39	33	4	39	49	13
Machinery & Equipment	11	11	1	19	21	3	50	58	28
Other Manufacturing Industries	N	20	2	N	40	5	N	70	27
Sample[b]	**14**	**17**	**2**	**23**	**29**	**9**	**33**	**39**	**20**

[a] includes all components of loadshedding costs, except labour-related adjustment costs which lead to a redistribution between wages and profits onlyleaving value added unaffected.

[b] Sample adjusted for the underlying population distribution of units by industry.

[c] Corresponds to the difference between the proposed investment plan over the next five years with and without loadshedding.

for small-scale units and Rs.1.0 billion each for medium- and large-scale units in the industrial sector during the year under investigation. Therefore, almost 55 per cent of the national cost of loadshedding has been borne by the small-scale sector.

VII. Policy Implications

The analysis undertaken above has revealed that the differential impact of loadshedding by size of unit can be attributed, first, to the higher incidence of power shutdowns in the case of small and medium-sized units as compared to large units. Second, it may also be attributed to a higher proportion of output being lost permanently by such units due to their inability to adjust to outages through mechanisms like additional shifts, self-generation of power, etc.

Policy measures to reduce differentials in the impact of loadshedding will, therefore, have to be designed to work on both fronts. First, a load management strategy will have to be evolved to spread the burden more evenly, particularly in cases where it can be demonstrated that costs per KWH of energy not delivered are higher for small units, and where it is feasible for the power utility to bring about such a redistribution. Second, support will have to be provided to the small-scale sector to increase its ability to respond more effectively to outages, thereby mitigating the impact on value added and profitability.

Land Management Strategy:

It has been demonstrated above that given the pattern of distribution of loadshedding in 1984-85, there are a number of industries like textiles, wearing apparel and footwear, wood and paper, chemicals, non-metallic mineral products and machinery and equipment, where costs per KWH of loadshedding are higher for small units. Therefore, a case exists purely on efficiency grounds for diverting power away from large to small units. This can be achieved by reducing somewhat the priority attached to supplying feeders dedicated for consumption by large-scale units (excluding the continuous-process ones) and thereby releasing more energy for other uses, including that by small units. Alternatively, a more direct approach can be followed which seeks to enhance the availability of power in those parts of the distribution system where it is known that there is a higher concentration of small units. However, zoning provisions do not apply rigidly to the location of small industrial units within cities and, consequently, land use for this purpose tends to be interspersed with other uses. Therefore, both approaches run the risk of diverting scarce energy to low priority sectors like residential and commercial use, and cannot be used indiscriminately.

Instead, it is suggested that high priority be given to enhancing and protecting power supply to small-scale industrial estates in cities like Lahore, Gujranwala, Sialkot, Gujrat, etc.,[9] where bulk of the consumption is industrial in character and a high proportion of units are in industries where the cost of energy shortages is exceptionally high. Such a policy will ensure continued investment in these estates either by the relocation of some units or through the establishment of new units.

We turn next to support measures to enhance the ability of small and medium-sized units to respond more effectively to outages.

Information Flows to Consumers:

Responses to the survey questionnaire indicate either that WAPDA has not always kept to its pre-announced schedule of loadshedding or that sufficient prior information has not been given to consumers about impending shortages. This complaint has been voiced in particular by small units. More than half have generally been caught unaware by loadshedding and have, therefore, not been able to make appropriate adjustments in advance. These firms report that on the average they need a lead time of nine to twelve hours to prepare themselves for an outage.

Clearly, WAPDA will have to develop adequate early warning systems for power consumers, especially the small ones, and to the extent possible adhere to pre-announced schedules. These arrangements could include advance notices regularly in newspapers in local languages or, if possible, despatch of circulars with relevant information to consumers alongwith the monthly power bills.

Technical Extension Services:

The extent of variation in the level and nature of adjustments made by firms of similar size within an industry indicates that firms, particularly the smaller ones, may not possess adequate management expertise to realise fully the possibilities for energy conservation or adjustment to outages. Given the high social costs of loadshedding, it can be argued that the power utility, which is publicly owned, must go beyond an essentially passive information providing role, to a more active one of becoming a direct participant in the process of adjustment by firms to outages. As such, it may develop a subsidised consumer outreach program, especially for small-scale industrial units, which promotes energy conservation measures, steps to improve the power factor and methods of limiting peak demand.

[9] Pasha, *et al.*, (1986) have collected data on a sample of industrial estates in Pakistan on the availability of infrastructure, including power. The extent of loadshedding appears to be relatively high in the industrial estates of Punjab. In the Gujrat industrial estate, for example, loadshedding occurred for 6 to 8 hours daily between January 1985 to September 1985. A large proportion of units in this estate are in non-metallic mineral products, machinery and equipment industries which have a high degree of vulnerability to loadshedding.

Credit for Investment in Self-Generation:

The earlier analysis has demonstrated that even though benefits to small units of investment in generators are greater because of the higher incidence of loadshedding and the relatively short payback period for such investments, only a small minority have actually invested in stand-by generation capacity. The basic reason for this may be the lack of capital. Therefore, financial institutions like the Industrial Development Bank of Pakistan or the Small Business Finance Corporation may be motivated to establish a special credit line on easy terms and ready access to enable small firms to insulate themselves from outages by installing generators.[10]

Finally, it must be emphasized that to the extent any reduction in the overall incidence of loadshedding differentially benefits small firms, the value to society of investment in expanded power generation can be seen in terms of savings in value added primarily to such entities. The research indicates that the costs per KWH of outages are high, over $2\frac{1}{2}$ times the marginal cost of power generation and distribution.[11] The economic justification for higher development allocations for the energy sector is consequently very strong. This will not only yield higher levels of net value added for the economy as a whole, but also avert a significant deterioration in the inter-personal and inter-regional distribution of income in the country.

Applied Economics Research Centre
University of Karachi

[10] A policy of encouraging self-generation has the implication that foreign exchange costs may be higher because stand-by units use imported oil products whereas public supply generating capacity is based on hydro-electricity or indigenous fuels like gas, etc.

[11] The marginal cost of generation and transmission in 1984-85 for the most recent vintage of thermal power station was Rs.2.82 per KWH at the point of delivery to consumers. This estimate allows for transmission losses at existing levels.

References

Anderson, R., and L. Taylor, 1986, The social cost of unsupplied electricity, Energy Economics, 8(3): 139-146.

Bental, B., and S. David, 1982, A simple method for evaluating the marginal cost of unsupplied electricity, The Bell Journal of Economics, 13(1): 249-253.

Crew, M., and P. Kleinderfer, 1978, Reliability and public utility pricing, American Economic Review, 68(1): 31-40.

Mattson, B., 1966, Economy versus reliability in Sweden, IEEE Spectrum.

Munasinghe, M., and M. Gellerson, 1979, Economic criteria for optimising power system reliability levels, The Bell Journal of Economics.

Munasinghe, M., 1979, The economics of power systems reliability and planning, Baltimore: Johns Hopkins University Press.

Munasinghe, M., 1981, Optimal electricity supply: Reliability, pricing and system planning, Energy Economics, 3: 140-152.

Pasha, H.A., A. Ghaus and S. Malik, 1989, The economic cost of power outages in the industrial sector of Pakistan, Energy Economics, 11(4): 301-318.

Pasha, H.A., Z.H.Ismail, N. Ahmad and A. Wasti, 1986, Fiscal incentives and regional industrial development, Research Report No.25, Karachi: AERC.

Planning Commission, Government of Pakistan, 1988, The Seventh Five Year Plan, Islamabad.

Sanghvi, Arun P., 1982, Economic costs of electricity supply interruptions: US and foreign experience, Energy Economics, 4: 180-198.

Sanghvi, Arun P., 1983, Optimal electricity supply reliability using customer shortage costs, Energy Economics, 5: 129-136.

Telson, M.L., 1975, The economics of alternative levels of reliability for power generation systems, The Bell Journal of Economics, 6: 679-694.

APPENDIX I

Methodology of Quantifying Loadshedding Costs

Firms frequently make adjustments in their operations to recover at least some of the output lost during and immediately after outages. Therefore, part of the cost of outages consists of direct costs which primarily comprise the spoilage cost and net value of lost production, hitherto referred to as 'idle factor cost'. The remainder consists of adjustment costs.[1]

We first describe the methodology used for deriving the magnitude of direct costs.

Direct Costs:

Spoilage costs:

The economic value of the spoilt product depends upon the value of raw materials and other inputs ruined, as well as on the value added embodied in the output that is destroyed (if any). In some industries, spoilage may occur instantly, whereas in others the outage would have to be of some minimum duration before any significant losses are experienced. Also, the extent of spoilage could be a function, not only of the duration, but also of the anticipated or unanticipated nature of the outage.

For a particular firm we define the following:

n_i^o = number of times of occurrence of planned outage of duration[2], d_i, in the year;

n_i^1 = number of times of occurrence of unplanned outage of duration, d_i, in the year;

$s^o(d_i)$ = spoilage cost in Rupees due to an planned outage of duration, d_i;

$s^1(d_i)$ = spoilage cost in Rupees due to an unplanned outage of duration, d_i;

with $s^o(d_i) \geq 0$, $s^1(d_i) \geq 0$, $s^1(d_i) \geq s^o(d_i)$.

[1] The approach used by us for quantifying outage costs essentially involves estimation of the value added impact of outages in ter the change in wages and profits arising from these outages. The impact on profits alone would come close to a willingness-to-pay measure of outage costs.

[2] The analysis has been carried out in terms of four duration intervals: up to half hour, more than half hour up to one hour, more than one hour up to two hours, more than two hours.

The total spoilage cost, SPC, then is given by

$$SPC = \sum_{i=1}^{m} s^o(d_i)\ n_i^o + \sum_{i=1}^{m} s^1(d_i)\ n_i^1 \qquad (1)$$

Idle Factor costs:

During the power interruption, a certain fraction, ε_1, $(0 < \varepsilon_1 \leq 1)$, of the normal output will be lost. In addition, a further proportion, ε_2, $(0 < \varepsilon_2 \leq 1)$, may also be lost during the restart period. The total output lost will then be the sum of the foregone output during and after the outage. The cost of this foregone output is referred to as the idle factor cost because during this period both labour and capital remain unemployed.

For a particular firm we define the following additional variables:

$\varepsilon_1^o(d_i)$ = proportion of output lost during planned outage of duration d_i;

$\varepsilon_1^1(d_i)$ = proportion of output lost during unplanned outage of duration d_i;

$\gamma^o(d_i)$ = restart period following planned outage of duration d_i;

$\gamma^1(d_i)$ = restart period following unplanned outage of duration d_i;

$\varepsilon_2^o(d_i)$ = proportion of output lost during restart period following planned outage of duration d_i;

$\varepsilon_2^1(d_i)$ = proportion of output lost during restart period following unplanned outage of duration d_i;

V = value added by the firm;

h = number of hours worked by the firm;

with

$0 < \varepsilon_1^o(d_i) \leq 1,\ 0 < \varepsilon_1^1(d_i) \leq 1,\ 0 < \varepsilon_2^o(d_i) \leq 1,\ 0 < \varepsilon_2^1(d_i) \leq 1$

$\gamma^o(d_i) \geq 0,\ \gamma^1(d_i) \geq 0,\ \varepsilon_1^o(d_i) \leq \varepsilon_1^1(d_i),\ \gamma^o(d_i) \leq \gamma^1(d_i),$

$\varepsilon_2^o(d_i) \leq \varepsilon_2^1(d_i).$

The total equivalent number of hours of production lost, LSH, is given by

$$LSH = \sum_{i=1}^{m} \{\varepsilon_1^{o}(d_i)\, d_i + \varepsilon_2^{o}(d_i)\, \gamma^{o}(d_i)\, n_i^{o} +$$

$$\sum_{i=1}^{m} \{\varepsilon_1^{1}(d_i)\, d_i + \varepsilon_2^{1}(d_i)\, \gamma^{1}(d_i)\, n_i^{1} \qquad (2)$$

and the idle factor cost by

$$IFC = LSH \bullet \frac{V}{h} \qquad (3)$$

However, in the presence of excess capacity during the period not affected by outages, firms may recover a certain proportion, λ, of the lost output. In order to determine λ we specify the following:

T = 'Target ' output of the firm;
Q = Actual output of the firm;
ϕ = Extent of divergence between target and actual output attributable to power outages;
h = Normal annual working hours of the firm.

The maximum possible output loss, MQL, due to power interruptions is given by

$$MQL = \frac{LSH}{\bar{h}}\, T \qquad (4)$$

where LSH is obtained from equation (2).

The corresponding actual output loss, AQL, is

$$AQL = \phi(T - Q) \qquad (5)$$

Therefore, the extent of output recovered, λ, is given by

$$\lambda = 1 - \frac{\bar{h}\,\phi}{LSH} \{1 - \frac{Q}{T}\} \qquad (6)$$

It may be noted that in the special cases, first, where $\phi = 0$, $\lambda = 1$, and second, when Q=T, $\lambda = 1$.

Given some recovery of output, the net idle factor cost, NIFC, is defined as

$$NIFC = (1 - \lambda)\, IFC \tag{7}$$

and the total basic direct cost, DC, as

$$DC = SPC + NIFC \tag{8}$$

Adjustment Costs:

Recovery of some of the output as a consequence of outages imposes certain adjustment costs on the firm. The nature and magnitude of these costs depends upon the type of adjustment that the firm makes.

This section develops the methodology for quantifying these adjustment costs.

At this stage, we define the following:

λ_1 = proportion of output recovered by more intensive utilization of existing capacity;

λ_2 = proportion of output recovered by working overtime;

λ_3 = proportion of output recovered by additional shifts;

with $\lambda_1 + \lambda_2 + \lambda_3 = 1$.

More Intensive Utilization Capacity:

Firms generally report higher repair and maintenance costs due to more intensive utilization of machinery. This represents the adjustment cost of moving to a higher rate of capacity utilization during the period not affected by outages.

Overtime Costs:

If the firm does not operate a 24 hour production schedule daily, then there exists some opportunity for overtime. Whether or not overtime is actually resorted to will depend upon the magnitude of overtime differential, the importance of labour costs in total costs of production and the extent to which the firm has the market power to transfer the higher costs on to the consumers.

The period of overtime, h_o, is given by,

$$h_o = \lambda_2\, \lambda\, LSH \tag{9}$$

with LSH from equation (2) and λ from equation (6). It is assumed at this stage that labour productivity during overtime is the same as that during normal production hours, and we define the following:

W = wage bill of the firm

θ_1 = overtime wage premium, $\theta_1 > 0$

then the overtime production cost, OPC, is derived as

$$OPC = \frac{W}{h}(1 + \theta_1)\, h_o \tag{10}$$

Additional Shift Cost:

A similar methodology can be followed for quantifying additional shift costs.

The number of additional shifts, a , is obtained as

$$a = \lambda_3 \lambda \frac{LSH}{h^*} \tag{11}$$

where h* is the duration of a typical shift.

The additional shift cost, ASC, is given by

$$ASC = \frac{W}{h}(1 + \theta_2)\, h^* a \tag{12}$$

where θ_2 is the magnitude of the shift differential.

The total indirect costs, IDC , are then derived as

$$IDC = IVC + OPC + ASC \tag{13}$$

This leads to the total cost, OC, of power outages as

$$OC = DC + IDC \tag{14}$$

For a substantial proportion of the firms, the above methodology is adequate for quantifying the economic costs of loadshedding and power outages.

Cost of Changes in Timings:

If a firm operates one or two shifts only, adequate slack time may be available to alter these shift timings in order to avoid or work around periods of maximum outages during a particular day.However, in the short run, given the fixity of contractual arrangements with labour, any major changes in shift timings are likely to result in additional labour costs for payment of shift differentials. But over time, as the pattern of outages gets established and firms begin to expect it to continue in the foreseeable future, then labour contracts may be renegotiated with built-in provisions for changes in shift timings.

Given a change in shift timings, the cost of power outages can be computed by defining the following:

$n_i^{o'}$ = number of times of occurrence of planned outages of duration d_i in the year following the new shift timings;

$n_i^{1'}$ = number of times of occurrence of unplanned outages of duration d_i in the year following the new shift timings.

The total spoilage cost, SPC', then is given by

$$SPC' = \sum_{i=1}^{m} S^{o}(d_i)\, n_i^{o'} + \sum_{i=1}^{m} S^{1}(d_i)\, n_i^{1'} \tag{15}$$

with the same $S^{o}(d_i)$ and $S^{1}(d_i)$ as in Equation (1).

Clearly, SPC' < SPC with SPC computed from Equation (1). Similarly, the idle factor cost, IFC, is given from Equations (2) and (3) by substituting $n_i^{o'}$ for n_i^{o} and $n_i^{1'}$ for n_i^{1}. Here also, IFC' < IFC. The contribution of the change in shift timings to profit of the firm, $\Delta\pi$, is given by

$$\Delta\pi = (SPC - SPC') + (IFC - IFC') \tag{16}$$

However, some additional indirect costs may have to be incurred as a consequence of the change in shift timings. This would primarily consist of the shift differential, SDC, (if any), in wages.

$$SDC = \left(\frac{W}{h} \bullet h^{*}\right) n_s \theta_3 \tag{17}$$

when n_s is the number of shifts operated in the year on the new timings and θ_3 is the wage differential. As changes in shift timings are in response to planned outages, all incremental costs of shift differentials are allocated to planned outages, and not to unplanned outages.

The total costs of outages in this case are given by

$$OC = SPC + IFC + SDC \tag{18}$$

It is assumed that no other adjustments besides the change in shift timings are made by the firm. If, however, the firm attempts to recover some of the lost output in this case by other mechanisms, for example, by more intensive utilization of capacity, then the same methodology can be adopted as developed above for indirect costs.

A, more ore less, identical procedure can be followed in the case of a firm which opts for a change in working days, for example, by working on Fridays, rather than changing the shift timings.

Generators Cost:

Another pattern of response by industrial units, which is being increasingly observed in Pakistan, is that of development of own sources of energy supply through investment in generators. As mentioned earlier, the profitability of such an investment becomes greater the larger the time losses due to outages and the stronger the expectation that relatively high levels of power interruptions will persist in the long run.

In practice, however, the extent of substitution of the conventional power source will depend upon the energy-intensity of operations, the extent of access to and cost of capital, on the possibility of making other cheaper adjustments and the ability of the firm to transfer the higher costs in the form of higher prices. Therefore, both partial and complete substitution of the standard power source by generators could be observed during periods of outages. We take up first the case of total substitution, by defining the following:

- K = normal power consumption in kw/h for production purposes by the firm;
- C(K) = capital cost of generators with combined capacity of K;
- O(K) = operating cost per hour of generators with combined capacity of K;
- t = tariff cost per kwh of the standard energy source (WAPDA).

The total hours lost, HRL, due to outages is given by

$$HRL = \sum_{i=1}^{m} d_i n_i^{o} + \sum_{i=1}^{m} d_i n_i^{1} \tag{19}$$

Therefore, the total cost, TGC, of operating the generators for this period is

$$TGC = C(K)\,[r + \delta] + O(K)HRL \qquad (20)$$

where r is the opportunity cost of capital and δ is the annual depreciation rate of generators.

The additional cost (corresponding to the total indirect cost) of power generation is NGC, where

$$NGC = TGC - t \bullet K \bullet HRL \qquad (21)$$

Since, in this case, generators totally substitute for WAPDA, there are likely to be no direct costs of planned outages, if the units are placed in operation prior to the start of the scheduled outages during the particular working shift.

Therefore, in this case,

$$OC = NGC \qquad (22)$$

We turn now to the case of partial substitution by generators. If Kg is the extent of power generation for production purposes by the generators available with the firm and Hg the number of hours for t which they are used, then the extent of substitution, ES, of the standard power source by self-generation is given by

$$ES = \frac{Hg \times Kg}{HRL \times K}, \ (ES < 1) \qquad (23)$$

and

$$TGC = C(Kg)\,[r + \delta] + O(Kg)Hg \qquad (24)$$

and the net generator cost is given by

$$NGC = TGC - t\,Kg\,Hg \qquad (25)$$

In this case, the total outage cost can be derived as

$$OC = (1 - ES)\,(DC + IDC) + ES \bullet NGC \qquad (26)$$

where DC and IDC are given by Equations (8) and (13) respectively.

Outage Cost per KWh:

The primary output from the above methodology is the estimated outage cost per KWH not delivered. If this is represented by OCKWH, then we have that

$$\text{OCKWH} = \frac{\text{OC}}{\text{HRL} \bullet \text{K}} \tag{27}$$

By identifying the separate components of direct and adjustment costs it is also possible to derive the economic cost per kwh of planned and unplanned outages respectively.

APPENDIX II

Economics of Investment in Generators

We want to find out the number of years it takes for investment in generators to pay for itself. Suppose this is T years. Then T is given by

$$C(K = \sum_{i=1}^{i=T} \frac{\ell \bullet L_i \bullet K - V(K, L_i)}{(1 + r)^i} + \frac{S(T)}{(1 + r)^T}$$

where

K = Capacity of generators,

ℓ = loadshedding cost per KWH,

L_i = number of hours of loadshedding,

$V(K, L_i)$ = variable cost of operating generators,

S(T) = scrap value in year t of generators.

We project the hours of loadshedding for each industry for each unit size:

$$L_i = L_o (1 - g)$$

The above analysis has been undertaken for average values by firm size at the industry group level, with g = 0, implying static expectations about future levels of loadshedding.

The magnitude of T estimated in the case of small units ranges generally from three to seven years.