The Pakistan Development Review
47:3 (Autumn 2008) pp. 227–246

The Cost of Unserved Energy: Evidence from Selected Industrial Cities of Pakistan

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This study is an attempt to explore the cost of unserved energy due to power outages in Pakistan that started in 2007. The study is based on a survey conducted for four major industrial cities of Punjab—Gujrat, Faisalabad, Gujranwala, and Sialkot. In addition to quantification of output losses, the effect on employment, cost of production, and delay in supply orders are also examined. The output loss is quantified using two-dimensional analyses, controlling for variations in the duration of outages and in the shift hours. The survey data reveal that employment has not suffered any significant drop due to alternative energy arrangements. These arrangements, nevertheless, have increased the production cost of the firms. Delays in the delivery of supply orders are also due to energy shortage. The study reports that the total industrial output loss varies between 12 percent and 37 percent, with Punjab as the major affected province. In the two dimensional analysis resulting in nine scenarios for each province, the ranges of losses in billion Rs are 132-400, 109-331, 17-54 and 11-34 for Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan respectively. The overall industrial sector loss in volume ranges between 269-819 billion rupees. In the overall analysis, food and beverages, textile, and chemical product industries are respectively the top three industries on the scale of losses. However, in terms of percentages, the pottery and ceramic industry is the industry that suffered the most.

JEL classification: Q4, L60
Keywords: Energy Crises, Output Loss, Manufacturing, Pakistan

1. INTRODUCTION

Pakistan has been experiencing the worst energy crisis of its history since 2007. The situation is getting worse with each passing year. It all began with electricity shortfall that gradually turned into deficit in other forms of energy such as gas and petroleum products when both households and firms resorted to these alternative sources of energy. The severe electricity shortfall compelled the authorities to impose load-

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Authors' Note: We owe special thanks to Zainab Iftikhar, Saba Anwar, for data compilation and useful suggestions and to Ghulam Saghir and Ahsan ul Haq Satti for their help in conducting the survey. The financial assistance for this survey was provided by the Pakistan Institute of Development Economics (PIDE), Islamabad. The authors are responsible for any errors or omissions. The views expressed are of the authors and may not be attributed to the institutions.

shedding schedules of more than eight hours at times; however unannounced outages in some cities could be as long as eighteen hours giving rise to a host of problems.

The fundamental reasons behind the current crisis include the slow growth in energy supply, lack of correct estimates for demand forecasts, water shortages, volatility in fuel prices, persistent high transmission and distribution losses, insufficient focus on development of alternative energy sources, the problem of circular debt and, above all, the lack of political commitment on the part of government to deal with these issues. Little or no attention was paid by concerned authorities to the galloping increase in demand and growing shortfall in generation. This is apparent in the absence of coordination between growth and energy policies of the government. [Nasir and Rehman (2011)]. This inefficient management has resulted in stagnant hydel and thermal power supply at 6400 MW and 12400 MW respectively, for the period 2002-2007. Similarly, the transmission and distribution losses of more than 20 percent of total energy supply are another evidence of gross negligence of this vital sector of the national economy. Shahbaz and Feridun (2011) for this reason call on policy-makers to devise proactive policies for investment in expanding generation capacity so that any likely increase in demand for energy is met without costly delays.

Energy-growth causality has been studied extensively in the energy literature. This issue has also been discussed in Pakistan where studies conclude that energy shortage may retard the growth process in the country [see, for instance, Siddiqui (2004) and Aqeel and Butt (2001) among others]. In particular, the industrial sector, being the most energy intensive sector, can be severely affected by this shortfall and subsequently can damage the overall economy. The reduction in output growth due to energy shortfall is also termed as the cost of unserved energy.[1] In other words, had the energy been supplied, the output would have been greater and the cost, in terms of lost output, would have been reduced. Various studies have tried to quantify this output loss due to power outages [see, for instance, Bental and Ravid (1982); Bose, *et al.* (2005); Wijayatunga and Jayalath (2008) and Kaseke (2010)].

The literature on this issue in Pakistan is scant and rare. To our knowledge, only two studies have been published to-date to quantify the production cost, namely, Lahore Chamber of Commerce and Industry (1986) and Pasha, *et al.* (1989). The objectives of the current study are twofold: in addition to quantification of output loss of industrial sector, it also explores the effect of outages in other sectors such as labour employment, cost of production, and supply orders delays. This study is different from the aforementioned studies in the sense that it performs a two dimensional analysis for quantification of variations in both outage duration and shift hours whereas the earlier studies focused on power outages only.

The rest of the study proceeds as follows: Section 2 discusses the development of power sector in Pakistan. Section 3 discusses the methodological issues. The survey results are analysed in Section 4. Section 5 quantifies the output losses for provinces and the country, while Section 6 concludes the study.

[1]Since their meanings are the same, throughout this study, the terms unserved energy, power outages, and loadshedding are used interchangeably.

2. POWER SECTOR DEVELOPMENT IN PAKISTAN

As a newborn state in 1947, Pakistan could generate 60MW of power, as its inherent ability, for 31.5 million people which provided around 4.5 units per capita for consumption. In 1952, the Government of Pakistan acquired the preponderance of shares of the Karachi Electric Supply Company (KESC) taking over the management of the generation, transmission and distribution of electric energy in and around the metropolitan city of Karachi covering all consumers—industrial, commercial, agricultural and domestic.

In 1958 a self-governing body of Water and Power Development Authority (WAPDA) was created to provide integrated development schemes in water and power sectors. Hitherto such projects were designed and incorporated by the respective electricity and irrigation departments of the provinces. By 1959, Pakistan had gathered pace in development and consequently required a more solid foundation of infrastructure with electricity being the most important component. WAPDA embarked on this task by increasing the power generation capacity to 119 MW, executing a number of hydel and thermal generation projects, and developing a transmission distribution network which could sustain the load of the rapidly increasing demand of electricity.

Within the first five years of its operation i.e. from 1959-60 to 1964-65 the electricity and power generation capacity had increased to 636 MW and 2,500 MKWH, from 119 MW and 781 MKWH respectively. By the year 1965, the number of electrified villages in the country increased to 1882 villages (688,000 consumers) as compared to 609 villages at the time of inception of WAPDA. This speedy and phased progress in infrastructure building spurred economic activities in the country, leading to mechanised agriculture in villages, industrialisation in urban areas and an improvement in the general living standards.

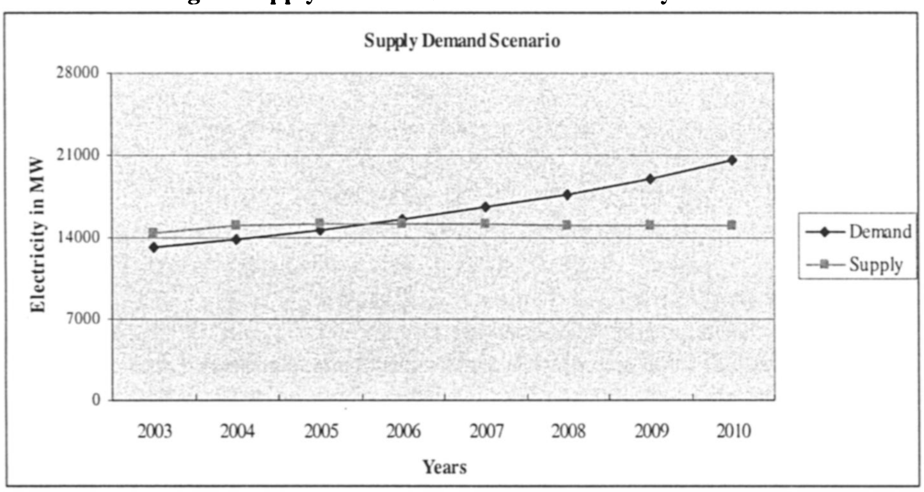
Power development had further accelerated by the year 1970. The commissioning of a number of thermal and hydel power units raised the power generation capability from 636 MW to 1331 MW. In 1980 this capability had increased to 3,000 MW which rose over the time and touched the capacity of 7,000 MW in 1990-91.

Even so, despite this apparently fast development of the electricity sector, energy demand had been outpacing generation owing to increasing urbanisation, industrialisation and rural electrification. Electricity consumption had been growing by 9-10 percent per annum since the 1970s. By around the early 1990s the shortage fell to a point that made resort to compulsory load shedding necessary. The shortfall was of the order of about 1,500 – 2,000 MW owing to 15-20 percent gap between demand and supply. Being an essential necessity, electricity demand has a comparatively low elasticity. On the supply side, inability of the public budget to meet the high investment requirement of the power sector led to a capacity shortage. This demand-supply gap had a serious impact on economic growth which fell to 4-5 percent per annum during the 1990s from a level of 6 percent per annum in the 1980s.

In 1993, government established an Energy Task Force to work out a consolidated and comprehensive policy for refurbishing the energy sector so that the power shortage/load shedding problem could be overcome. The Task Force produced a policy paper titled "Policy Framework and Package of Incentives for Private Sector Power Generation Projects" in March 1994 which recommended privatization of the energy sector on a large scale. It provided a number of incentives to attract foreign investment in the power sector including a fix levelised tariff of US$ 5.57/kwh to the prospective investors (US$ 6.1/kwh average for 1-10 years).This policy did help temporarily in tackling the load-shedding problem in the country. It even led to surplus production because the real growth in demand was lower than anticipated and the proposed projects were carried out over and above the requirement. Since this policy attracted mostly thermal projects, it resulted in a change in the hydel/thermal generation mix.

The year 2000 saw new electricity market restructuring and liberalisation changes which resulted in breaking of the one semi-autonomous body of WAPDA into four thermal power generating units, nine distribution units and one transmission and distribution unit; comprising fourteen companies in total. Government also privatized the KESC in November 2005. Currently, KESC and WAPDA are operating independently but they can supply power to each other through 220 KV double circuit transmission lines. As computed on June 30, 2008, Pakistan's total power generation capacity is 19,420 MW. It includes the total generation capacity of KESC, Independent Power Procedures (IPPs) and WAPDA's own hydel, thermal and nuclear resources. In spite of this generation capacity, still there is gap between supply and demand in power sector as demonstrated in Figure 1.

Fig. 1. Supply Demand Scenario of Electricity in MW



Source: Private Power and Infrastructure Board.

3. METHODOLOGICAL ISSUES

The survey was conducted in May-June 2008 in four major industrial cities of Punjab—Gujrat, Faisalabad, Gujranwala and Sialkot. For this purpose, 50 enumerators were hired who were supervised by four field supervisors. In case the owner was not available, the manager of the respective firm was interviewed to collect data.

A three-step filtration procedure was adopted to obtain the 'population' of firms. Initially, all the firms, which got registration with the Chamber of Commerce and Industry before 2008, were selected. This information about the firms was provided by the Chambers of Commerce and Industry of the aforementioned cities. Then, as a first step, the firms which were not operational at the end of 2007 were dropped. This filtration got us what is called 'initial population'. In the second step, those firms were omitted from this 'initial population' which were only trading goods, not producing. The firms that were left after this filtering made the population. In the last step, in order to avoid over-representation of small firms, we ignored the firms with less than 10 employees[2] [see, for instance, Alvarez and Hernando (2005) and Martins (2005)].

Next, we classified firms into ten different industry categories on the basis of their manufacturing activities. In this way, a total of 10 strata were obtained. Table 1 illustrates information regarding the industry groups, and the distribution of firms both by industry and by city.

Table 1

Distribution of Firms by Industry and by City

Industry Group	Faisalabad (%)	Gujranwala (%)	Gujrat (%)	Sialkot (%)	Firms
Food and Beverages	32	42	18	08	50
Textiles	68	13	08	11	85
Leather and Products	–	04	13	19	23
Wood and Furniture	05	26	68	–	19
Paper and Products	–	100	–	–	02
Chemical Products	55	36	–	09	11
Rubber and Plastic	05	59	23	14	22
Pottery and Ceramic	06	63	31	–	32
Iron and Metal	14	64	11	11	28
Machinery (E and NE)	16	51	33	–	67
Mean % (Total N)	**29 (99)**	**38 (129)**	**21 (72)**	**12 (39)**	**100 (339)**

Note: E and NE refers to electrical and non-electrical machinery.

Using random sampling within strata, and after controlling for 'no response' problem, a sample of 339 firms was selected which constitutes almost 8 percent of the total population. It goes without saying that the year 2007 is the reference year in the survey.

4. SURVEY RESULTS

In this section, the cost of un-served energy is assessed in terms of the effect of power outages on various dimensions of industrial sector. Power breakdowns lead to serious consequences. These include the effects on employment; production cost; and supply orders. Specifically, this section is based on the responses of firms to different questions asked in the survey. The information provided in this section is also helpful in quantification of output loss in the subsequent section.

4.1. Effect on Employment

The first matter of concern is related to the effect of load-shedding on employment of labour. Both supply and demand for labour can affect the employment level. In

[2]It should be confessed here that the impact on small units (having less than 10 employees) may be higher. However, currently data are not available for these sectors. This may under-estimate the impact of energy shortage.

Pakistan, however, supply of labour may not be a constraint due to the huge labour force available in the country. Supply shocks such as the power outages in the current case may, nonetheless, have an effect on labour demand due to power outages. During the outage time, for instance, the workers involved with the machinery operation may sit idle. It is, therefore, critical to investigate the effect of load-shedding on the labour hours. In this respect, the firms were asked about the loss of working hours per labour in a day due to power outages. Table 2 reports both overall and industry-wise responses. It is interesting to see that almost 31 percent of the total firms report either "no loss" or "less than 1 hour" loss. This suggests that these firms were able to utilise the workers either by manoeuvring their working hours or by going for alternative energy options such as using stand-by generators. On the other hand, however, more than 52 percent firms report the loss of more than 3 labour hours, signifying the adverse effect of unserved energy.

Table 2

Labour Hour Loss per Day by Industry

Industry Groups	No Loss	Less than 1 Hour	Between 1 to 3 Hours	Between 3 to 5 Hours	Between 5 to 8 Hours	Above 8 Hours	Total (N)
Food and Beverages	34.0	02.0	08.0	20.0	28.0	08.0	50
Textiles	31.8	04.7	10.6	16.5	31.8	04.7	85
Leather and Products	17.4	21.7	21.7	34.8	–	04.3	23
Wood and Furniture	10.5	–	26.3	36.8	21.1	05.3	19
Paper and Products	50.0	50.0	–	–	–	–	02
Chemical Products	27.3	18.2	18.2	09.1	27.3	–	11
Rubber and Plastic	18.2	04.5	18.2	40.9	13.6	04.5	22
Pottery and Ceramic	09.4	06.3	21.9	37.5	12.5	12.5	32
Iron and Metal	17.9	17.9	21.4	32.1	10.7	–	28
Machinery (E and NE)	20.9	04.5	23.9	31.3	16.4	03.0	67
Average % (Total N)	**23.6(80)**	**7.1(24)**	**17.1(58)**	**26.8(91)**	**20.4(69)**	**5.0(17)**	**100 (339)**

Furthermore, the results in Table 2 advocate that the firms in a particular industry are not facing the same situation. That is, each industry contains firms which face different losses of labour hours. This can also be confirmed from Table I in the Appendix where the average per day loss of labour hours along with minimum and maximum hours of loss for each industry is given.

It is evident from the table that the overall industrial sector losses in the sample area, on average, were 3.44 labour hours due to load-shedding, with paper and products being the least affected (0.50 hours) and potter and ceramic being the most affected (4.42 hours) industries. The table further reveals that in all industry groups there are firms with the minimum labour hour loss as zero, whereas for some firms (such as food and beverages, rubber and plastic, and potter and ceramics) the maximum loss reaches 12 hours. Together, these two tables show that load-management in these cities varies with location even within the same city.

Subsequently, we inspected the effect of load-shedding on labour demand. The information in the above two tables provides solid grounds to assess the undesirable effects on labour demand. Table 3 illustrates the responses of different industries regarding the reduction in labour demand due to energy crises. It is interesting to observe

Table 3

Labour Demand Reduction by Industry

Industry Group	No Change	Less than 5 Percent	Between 5 to 10 Percent	Between 10 to 20 Percent	Above 20 Percent	Total (N)
Food and Beverages	83.7	8.2	–	2.0	06.1	49
Textiles	79.8	–	2.4	1.2	16.7	84
Leather and Products	90.5	–	9.5	–	–	21
Wood and Furniture	52.9	–	5.9	–	41.2	17
Paper and Products	100.0	–	–	–	–	02
Chemical Products	90.9	–	–	–	09.1	11
Rubber and Plastic	100.0	–	–	–	–	21
Pottery and Ceramic	73.3	–	6.7	3.3	16.7	30
Iron and Metal	96.3	–	–	–	03.7	27
Machinery (E and NE)	77.8	3.2	6.3	3.2	09.5	63
Average % (Total N)	**81.8(266)**	**1.8(6)**	**3.4(11)**	**1.5(5)**	**11.4(37)**	**100(325)**

that almost 82 percent firms of the overall industrial sector report no change in labour demand. Moreover, except for paper and product industry, at least 70 percent of the firms in each industry testify that they have not reduced the labour demand due to energy crises. These results seem surprising but not unreasonable. Firstly, the possible reason for avoiding reduction in labour demand may be that the firms may have opted for alternative energy arrangements to sustain their production activity. Secondly, and rather more importantly, this survey was conducted in the second quarter of 2008, which was the early era of the outages and the firms may have considered the crisis to be short-lived. Thirdly, the firms may have adjusted the working hours. Ergo, in order to avoid the cost of firing and rehiring (at the end of the crisis) they retained the workers which might have prevented significant reduction in labour demand. Lastly, the firms may have excluded daily-wage workers from their labour statistics while reporting their response to this question, and consequently, may not have considered them as part of their labour demand. Nonetheless, the second reason is valid for the short-run and not for the long-run. Hence, the survey results of a post 2010 data may show significantly different results regarding layoffs from the one obtained using this data. It is important to bring it to the knowledge of the readers that, in spite of the results in Table 3, one may not strictly conclude that there is no association between power outages and labour demand reduction. The chi-square test in Table II in the Appendix concludes that the two variables are not independent of each other. Finally, it may be a result of weak substitutability between energy and labour [see Mahmood (1992)].

4.2. Alternative Energy Arrangements and Production Cost

As is discussed previously, the small reduction in labour demand by the firms may have resulted from alternative energy arrangements by these firms. In order to scrutinise the validity of this argument, the firms were asked about such arrangements. Their responses are given in Table 4. It can be seen from the table that almost 76 percent of the total firms have opted for alternative energy arrangements, mostly standby generators. Among the total firms, 22 percent used gas based generators and 54 percent used petroleum based generators. These results are important in two respects; first, they

Table 4

Alternative Energy Arrangements by Source and by Industry

Industry Group	Gas	Petroleum	None	No. of Firms
Food and Beverages	10.00	54.00	36.00	50
Textiles	34.12	36.47	29.41	85
Leather and Products	08.70	73.91	17.39	23
Wood and Furniture	05.26	68.42	26.32	19
Paper and Products	00.00	100.00	00.00	02
Chemical Products	09.09	81.82	09.09	11
Rubber and Plastic	40.91	59.09	00.00	22
Pottery and Ceramic	15.63	46.88	37.50	32
Iron and Metal	21.43	50.00	28.57	28
Machinery (E and NE)	22.39	62.69	14.93	67
Average % (Total N)	**21.83(74)**	**53.98(183)**	**24.19(82)**	**100(339)**

explain the small reduction in labour demand, and second, they bring to light one of the reasons for gas shortfall that the country is currently facing. In addition, the demand for petroleum products may have also increased immensely due to use of petroleum- based generators by the firms. This, together with the purchase of imported generators by the firms, might have contributed significantly to the import bill for Pakistan.[3]

Intuitively, it makes sense to believe that alternative energy arrangements will lead to increase in the cost of production. When inquired, 85 percent of these firms responded positively as is exhibited in Table 5. Withal, 55 percent of the total firms registered the increase in cost of production between 1 to 20 percent. For most of the industries, the majority of firms faced less than 10 percent increase in cost. The average increase in cost of production for the entire industrial sector is 26.5 percent.[4] This is perturbing, especially when 30 percent of the firms reported above 20 percent increase in their production cost. With such ever-increasing production cost of the firms, retaining workers by the firms would mean that they have transferred this increase to consumers thereby reducing the consumer surplus. The surge of inflation rate to more than 12 percent in recent years reflects the transference of the rising cost to prices of final goods. Accordingly, the continuous increase in price level in recent years may also be attributed to the recent energy crises which may rightly be termed as a supply shock. This notion also acquires support from Nasir and Malik (2011) who conclude that supply side shocks account for 70 percent of inflation variability in Pakistan.[5]

[3]The firms were also asked about the imported generators. 75 percent of the firms which opted for alternative energy arrangements responded that they purchased imported generators. See Table III in Appendix for detailed industry-wise responses.

[4]See Table IV in Appendix for industry-wise average increase in cost of production.

[5]However, a new study should be conducted to investigate exactly how much of this rise in cost is transferred to consumers, and whether or not some portion of the cost is transferred to labour in the form of real wage reduction or alternatively some portion of the profit is forgone.

Table 5

Percentage Increase in the Cost of Production by Industry

Industry Group	No Change	Less than 10 Percent	Between 10 to 20 Percent	Between 20 to 30	Between 30 to 50 Percent	Above 50 Percent	Total (N)
Food and Beverages	12.0	56.0	08.0	–	08.0	16.0	25
Textiles	20.5	22.7	22.7	15.9	–	18.2	44
Leather and Products	41.2	17.6	05.9	11.8	05.9	17.6	17
Wood and Furniture	–	58.3	08.3	–	–	33.3	12
Paper and Products	–	50.0	50.0	–	–	–	2
Chemical Products	–	57.1	–	–	14.3	28.6	7
Rubber and Plastic	26.7	40.0	13.3	20.0	–	–	15
Pottery and Ceramic	22.2	38.9	22.2	–	16.7	–	18
Iron and Metal	05.9	35.3	11.8	23.5	05.9	17.6	17
Machinery (E & NE)	06.3	45.8	20.8	02.1	14.6	10.4	48
Total % (N)	**15.1(31)**	**39.0(80)**	**16.1(33)**	**8.3(17)**	**7.3(15)**	**14.1(29)**	**100(205)**

4.3. Effect on Supply Orders

Delays in supply orders could be another potential cost of un-served energy. The survey results reveal that 69 percent of total firms confirmed delays in supply orders, whereas the rest of the firms (31 percent) were able to supply the orders on time probably due to the alternative energy arrangements. However, it is important to note that 76 percent of the firms opted for these arrangements while only 31 percent were able to avert the delays in supply. This means that the remaining 45 percent could not manage to meet the deadlines. The chi-square test in Table II also confirmed the strong dependence between load shedding and delays in supply orders. This situation is worrisome for the reason that these industries produce goods to not only meet domestic demand but also for export to earn foreign exchange for the country. Precisely, the delay in orders by 67.5 percent firms of textile industry and 62 percent firms of leather industry is an alarming situation as together these two industries constitute 57.2 percent share of the country's total exports.

It is needless to mention that the other industrial groups, listed in Table 6, also contribute significantly to exports. Therefore, delays in supply orders and especially of

Table 6

Delays in Supply Orders by Industry

Industry Group	No	Yes	Firms
Food and Beverages	42.2	57.8	45
Textiles	32.5	67.5	83
Leather and Products	38.1	61.9	21
Wood and Furniture	27.8	72.2	18
Paper and Products	100.0	-	02
Chemical Products	36.4	63.6	11
Rubber and Plastic	31.8	68.2	22
Pottery and Ceramic	29.0	71.0	31
Iron and Metal	28.6	71.4	28
Machinery (E & NE)	18.5	81.5	65
Mean % (Total N)	**31(101)**	**69(225)**	**100(326)**

export orders would portray a poor image of these industries both domestically and abroad, resulting in loss of clients and, as a consequence, foreign exchange reserves. In addition, this poor image would also scare away domestic and international prospective customers of the industrial as well as other sectors' products.

5. QUANTIFICATION OF OUTPUT LOSS

5.1. Methodology

This section quantifies the cost of unserved energy in the form of output loss. Table V in the Appendix explicates that 70 percent of total firms confronted output losses due to these breakdowns. The test of independence (chi-square test) in Table II also confirmed that there is close association between unserved energy and production loss. Hence, the loss is, primarily, calculated for ten different industries in Punjab both in volume and as percentage of total output in the respective industry. Afterwards, these factors (percentages) are used to calculate output losses for other provinces and for the country as a whole. In order to avoid any bias regarding the hours of work in a shift, we make three different cases of shift hours; 12 hours shift; 10 hours shift; and 8 hours shift.[6] This also deals with the issue of overtime work-hours. Likewise, the uncertainty regarding the duration of load-shedding in a particular year also compels us to make three different scenarios for the extent of power outages. These scenarios include power outages in six months, nine months, and throughout the year. Overall, therefore, we have nine different scenarios.

Industry-wise estimation of production loss required data on total outputs, number of workers, annual work days, and per day labour hour loss due to outages of the respective industries. Data on first three variables are taken from Census of Manufacturing Industries [CMI; 2005-06], whereas that on the fourth variable is taken from Table I in the Appendix based on the survey of firms. The use of 2005-06 as reference year for CMI data is appropriate as this is the last year before energy crises hit the country in 2007.

After data on these variables are acquired, the first step is the multiplication of shift hours with the number of workers to calculate the daily work hours of a particular industry. The product is then multiplied with annual work days to get annual work hours.

$$AWH_{zi} = L_z \times SH_i \times AWD_z \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where SH_i, L_z, AWD_z and AWH_z represent shift hours, number of workers, annual work days and annual work hours respectively. The subscript i denotes the length of shifts (in hours) which takes the values 12, 10, 8; whereas subscript z is representative of industry and its value varies from 1 to 10 in the same order as appeared in Table 1. The total annual output, which is given in CMI (2005-06), is then divided by annual work hours to find out output per labour hour.

[6]It should be noted that this quantification (of output loss) is based only on idle factor cost and does not include other cost such as spoilage cost, overtime cost and adjustment costs. In this sense, the loss obtained here may be underestimated.

$$OLPH_{zi} = Y_z / AWH_{zi} \quad \ldots \quad (2)$$

Here Y_z and $OPLH_z$ represent the annual output and output per labour hour in a particular industry. Next we require the total loss of labour hours (TLH_{zj}) in a particular industry, which is obtained by the multiplication of per day average loss of labour hours (ALH_z), total number of workers and work days (WD_{zj}) of the respective industry.

$$TLH_{Zj} = ALH_Z \times L_z \times WD_{zj} \quad \ldots \quad (3)$$

The subscript j is used to separate the duration of outages (in months) such as 12, 9 and 6 months. It is important to observe that in the special case when $j = 12$, WD_{zj} would be equal to AWD_z. Finally, combining Equations (2) and (3) gives us output loss for nine different scenarios.

$$O_{ij}^{z} = OPLH_{zi} \times TLH_{zj} \quad \ldots \quad (4)$$

O_{ij}^{z} in the above equation represents total output loss for ten industrial groups in nine different scenarios. In order to find the loss in percentage, the calculated annual loss is divided by the total annual output of the year 2005-06.

5.2. Output Loss for Punjab

This section expounds the quantification of production loss in the province of Punjab. Table 7 describes industry wise losses, both in volumes and in percentages, for all the nine scenarios. It is evident from the results of Table 7 that the maximum loss occurs in a scenario where the shift hours are eight and load-shedding occurs throughout the year. Conversely, minimum loss is observed for a twelve hours shift with six months load-shedding. Therefore, these two scenarios can be used as the lower and upper limits for losses.

Table 7 is very useful in the sense that it also gives the monetary value of the quantified output loss for each industry. It is obvious that, in terms of volume, the food and beverages industry suffered the most where the unserved energy cost the industry in the range of 56-172 billion rupees. This huge cost cannot be attributed to higher number of firms in the selected sample. In fact, the textile industry, which is the second most affected industry in terms of volume, has the highest share in our sample. In the same context, the third industry that encountered huge cost due to unserved energy is the chemicals industry. Although together these three industries contribute conspicuously to the overall industrial sector loss in absolute terms, yet adjudging them as the three major affectees would be misleading. The appropriate way to investigate industries that suffered the most would be to compare the losses of industries to their total annual outputs. In other words, the percentage losses should be analysed.

Table 7

Estimation of Production Loss for Punjab

Industries	Shift Hours	AL	AL%	9ML	9ML%	6ML	6ML%
	12	114.57	29.08	84.750	21.51	56.500	14.34
Food and Beverages	10	137.48	34.90	101.700	25.82	67.800	17.21
	08	171.85	43.63	127.125	32.27	84.750	21.51
	12	68.39	14.92	50.596	11.03	33.731	7.36
Textiles	10	82.07	17.90	60.715	13.24	40.477	8.83
	08	102.59	22.38	75.894	16.55	50.596	11.03
	12	3.27	17.58	2.423	13.01	1.615	8.67
Leather and Products	10	3.93	21.10	2.908	15.61	1.939	10.41
	08	4.91	26.38	3.635	19.51	2.423	13.01
	12	0.60	32.67	0.449	24.16	0.299	16.11
Wood and Furniture	10	0.72	39.20	0.539	29.00	0.359	19.33
	08	0.91	49.00	0.673	36.25	0.449	24.16
	12	2.01	4.17	1.491	3.08	0.994	2.05
Paper and Products	10	2.41	5.00	1.789	3.70	1.193	2.47
	08	3.02	6.25	2.236	4.62	1.491	3.08
	12	28.96	23.50	21.429	17.38	14.286	11.59
Chemical Products	10	34.76	28.20	25.714	20.86	17.143	13.91
	08	43.45	35.25	32.143	26.08	21.429	17.38
	12	1.65	30.33	1.220	22.44	0.814	14.96
Rubber and Plastic	10	1.98	36.40	1.465	26.93	0.976	17.95
	08	2.47	45.50	1.831	33.66	1.220	22.44
	12	17.80	36.83	13.170	27.25	8.780	18.16
Pottery and Ceramic	10	21.36	44.20	15.805	32.70	10.536	21.80
	08	26.70	55.25	19.756	40.87	13.170	27.25
	12	13.76	24.17	10.179	17.88	6.786	11.92
Iron and Metal	10	16.51	29.00	12.214	21.45	8.143	14.30
	08	20.64	36.25	15.268	26.82	10.179	17.88
	12	15.92	28.42	11.777	21.02	7.851	14.01
Machinery (E & NE)	10	19.10	34.10	14.132	25.22	9.422	16.82
	08	23.88	42.63	17.666	31.53	11.777	21.02
	12	266.93		197.484		131.656	
Total Losses	10	320.32		236.981		157.988	
	08	400.42		296.227		197.484	

Note: AL, 9ML and 6ML show annual, nine-month and six-month losses in billion rupees respectively.

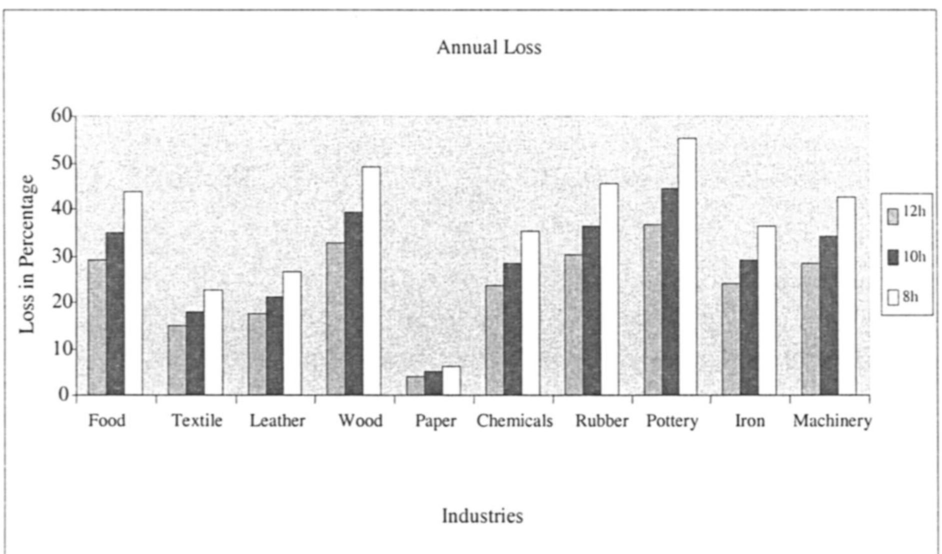
The industry wise percentage losses are also given in Table 7. However, for comparative analysis, graphical elucidation is more suitable. For this purpose, three figures are constructed to cover both dimensions. The three figures respectively show industry-wise annual, nine-month and six-month losses, each covering the variations in shift hours. Consequently, Figure 1 exhibits percentage losses for all industries for the case when outages occur throughout the year. It is obvious that, contrary to losses in absolute terms, in this case the pottery, ceramics and glass industry suffered the most with 55 percent loss in output for an eight hours shift. This may be due to the fact that among all these ten industries, the pottery, ceramics and glass industry is the most energy intensive as it requires 20 rupees of energy expenditure for the production of 100 rupees of output.[7] Furthermore, the wood and rubber industries are ranked second and third respectively in this list. The same trend holds for other shift hours as well. The food and beverages industry comes at fourth place in this list. Surprisingly, the textile industry, which suffered the second highest loss in volume, appears ninth on the list just before paper industry. Thus, we can safely conclude that the glass, wood, and rubber are respectively the three most affected industries in terms of their output loss due to unserved energy.

[7]The energy intensity is calculated by using CMI (2005-06) data.

Figure 1 also reveals a couple of points that call for explanation. The first is related to changes in percentage loss due to variations in shift hours. That is, for all industries the loss is maximum for the eight hours shift but minimum for twelve hours shift. It is because the calculation of output loss is based on the per day labour hours lost due to outages. Furthermore, except for textile industry, all other industries have one shift per day. This makes per day hours' loss equivalent to the per shift hours' loss. Subsequently, the extent of loss depends on the hours in shift. For example, an industry, say food and beverages industry, faces 4 labour hour loss in a shift. If the shift is of 8 hours, then the loss in labour hours is 50 percent for this industry. However, if it be a 12 hours shift, then this loss would reduce to 33 percent and so does the output loss. Thus, increasing shift hours lessens production loss.

The second is related to lower percentage loss of some industries despite their colossal absolute cost. The obvious example in this regard is that of the textile industry. The lower percentage loss is in fact an evidence of the huge output base. The more the industry is titanic in it total output, the lesser will be the percentage loss. For example, the highest possible loss to the textile industry in the study in hand is nearly 103 billion rupees. But the total annual output of this industry is 458.5 billion rupees due to which its percentage loss is around 22 percent; the second lowest in the list of the mentioned 10 industries.[8] The explanations for both these points hold for Figure 2 and Figure 3 as well. It is obvious from these two figures that the behaviours and trends of the percentage losses are the same except for reduction in their values. The respective reductions in the values are due to relatively lower amount of load-shedding in these cases.

Fig. 2. Annual Output Loss by Industry and by Shift Hours



[8]It is important to mention here that the textile industry not only operates two shifts a day but is also flexible in working hours and this may possibly be one of the reasons for its relatively high annual output.

Fig. 3. Nine Months' Output Loss by Industry and by Shift Hours

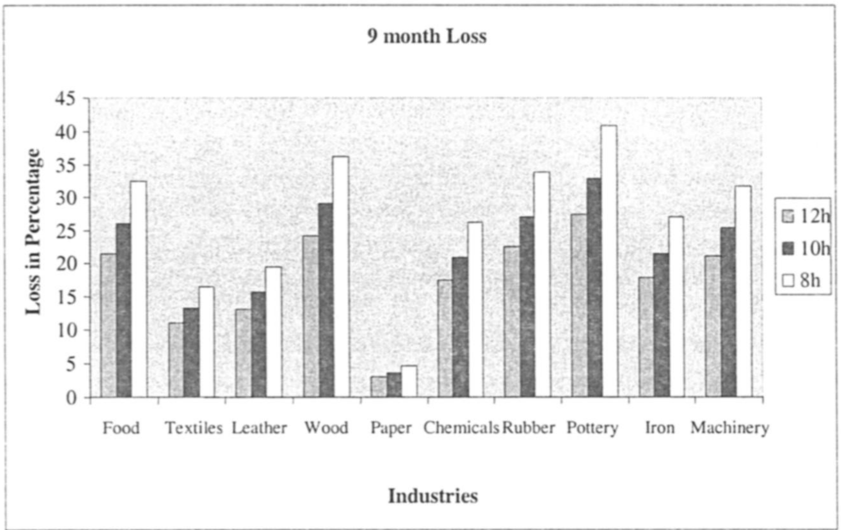
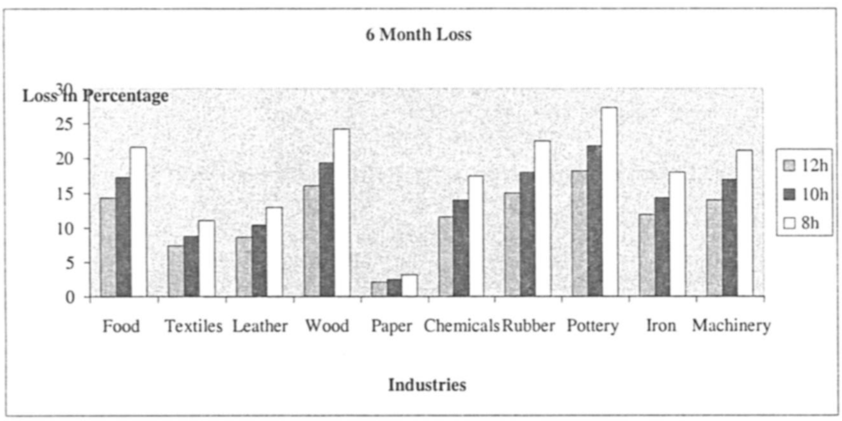


Fig. 4. Six Months' Output Loss by Industry and by Shift Hours



5.3. Output Loss for other Provinces and Pakistan

This sub-section explicates the quantification of output losses in the rest of the provinces and, subsequently, for the overall country. For this purpose, the factors (percentages) calculated for different industries in Punjab are imitated for others, assuming that the energy shortfall, and hence the labour hours loss, is the same for other provinces as in Punjab. This assumption may be optimistic but not unreasonable as the whole country was exposed to the energy crises since the onset of 2007. Questions can also be raised about other characteristics of the industries in these provinces. However, the purpose here is to give an approximation of the losses for these provinces to provide a makeshift sketch of the dismal situation these industries are in. Having said that, the authors are not hesitant in accepting the fact that these estimates can be improved further with a country-wide primary data study.

Table 8 gives the output losses for the provinces of Sindh, Balochistan, Khyber Pakhtunkhwa and then for Pakistan as a whole. Since the factors (percentages) are the same as that for Punjab, only the absolute (in volume) losses are reported in the table. It is interesting to observe that major affected industries vary across provinces. Thus, in Sindh the three most suffered industries are textile, food and beverages, and chemical products respectively. In Balochistan, these are the chemical products, textile, and pottery and ceramics. In Khyber Pakhtunkhwa, however, pottery and ceramics, food and beverages, and textile industries top the list. Since the factors are the same, these differences are the result of variation in annual outputs in different provinces of the same industries. The total loss to aggregate industrial sector of the country is then calculated by adding the losses for all provinces.

Table 8

Estimation of Production Losses for Provinces and for Pakistan (Billion Rs)

		Sindh			Balochistan			KP			Pakistan		
Industries	S. H	AL	9ML	6ML	AL	9ML	6ML	AL	9ML	6ML	AL	9ML	6ML
	12	46.26	34.22	22.81	3.50	2.59	1.73	11.70	8.66	5.77	176.03	130.22	86.81
Food and Beverages	10	55.51	41.06	27.38	4.20	3.11	2.07	14.04	10.39	6.93	211.23	156.26	104.18
	08	69.39	51.33	34.22	5.25	3.89	2.59	17.55	12.99	8.66	264.04	195.34	130.22
	12	74.49	55.10	36.73	5.36	3.96	2.64	3.40	2.52	1.68	151.65	112.18	74.78
Textiles	10	89.38	66.12	44.08	6.43	4.76	3.17	4.08	3.02	2.01	181.97	134.62	89.74
	08	111.73	82.65	55.10	8.04	5.95	3.96	5.10	3.78	2.52	227.47	168.27	112.18
	12	4.70	3.48	2.32	–	–	–	0.01	0.01	0.00	7.99	5.91	3.94
Leather and Products	10	5.64	4.17	2.78	–	–	–	0.01	0.01	0.00	9.58	7.09	4.72
	08	7.05	5.22	3.48	–	–	–	0.01	0.01	0.01	11.97	8.87	5.91
	12	1.98	1.47	0.98	1.07	0.79	0.53	0.18	0.14	0.09	3.84	2.85	1.90
Wood and Furniture	10	2.38	1.76	1.17	1.29	0.95	0.63	0.22	0.16	0.11	4.62	3.41	2.27
	08	2.97	2.20	1.47	1.61	1.19	0.79	0.28	0.20	0.14	5.77	4.26	2.85
	12	0.12	0.09	0.06	0.07	0.05	0.03	0.11	0.08	0.05	2.32	1.71	1.13
Paper and Products	10	0.14	0.10	0.07	0.08	0.06	0.04	0.13	0.10	0.06	2.77	2.05	1.36
	08	0.18	0.13	0.09	0.10	0.07	0.05	0.16	0.12	0.08	3.46	2.56	1.71
	12	45.33	33.53	22.36	5.72	4.23	2.82	2.00	1.48	0.99	82.02	60.67	40.46
Chemicals Products	10	54.40	40.24	26.83	6.87	5.08	3.39	2.41	1.78	1.19	98.44	72.81	48.55
	08	68.00	50.30	33.53	8.59	6.35	4.23	3.01	2.22	1.48	123.05	91.01	60.67
	12	4.97	3.68	2.45	1.00	0.74	0.50	2.10	1.55	1.04	9.72	7.19	4.80
Rubber and Plastic	10	5.96	4.41	2.94	1.21	0.89	0.59	2.52	1.86	1.24	11.67	8.63	5.75
	08	7.46	5.51	3.68	1.51	1.11	0.74	3.15	2.33	1.55	14.60	10.78	7.19
	12	14.37	10.63	7.08	3.61	2.67	1.78	13.65	10.10	6.73	49.44	36.57	24.37
Pottery and Ceramic	10	17.24	12.75	8.50	4.34	3.21	2.14	16.38	12.12	8.08	59.33	43.89	29.26
	08	21.55	15.94	10.63	5.42	4.01	2.67	20.48	15.15	10.10	74.16	54.86	36.57
	12	15.24	11.27	7.52	1.00	0.74	0.49	0.66	0.49	0.33	30.66	22.68	15.13
Iron and Metal	10	18.29	13.53	9.02	1.20	0.89	0.59	0.79	0.59	0.39	36.79	27.22	18.14
	08	22.86	16.91	11.27	1.50	1.11	0.74	0.99	0.73	0.49	45.99	34.02	22.68
	12	13.11	9.70	6.46	1.14	0.84	0.56	2.32	1.72	1.14	32.49	24.04	16.01
Machinery (E & NE)	10	15.73	11.63	7.76	1.37	1.01	0.67	2.78	2.06	1.37	38.99	28.83	19.22
	08	19.66	14.54	9.70	1.71	1.27	0.84	3.48	2.57	1.72	48.73	36.05	24.04
	12	220.5	163.1	108.7	22.4	16.6	11.0	36.1	26.7	17.8	546.1	404.0	269.3
Total Losses	10	264.6	195.7	130.5	26.9	19.9	13.2	43.3	32.0	21.3	655.3	484.8	323.1
	08	330.8	244.7	163.1	33.7	24.9	16.6	54.2	40.1	26.7	819.2	606.0	404.0

Note: S.H. and KP denotes Shift Hours and Khyber Pakhtunkhwa respectively.

This is not surprising as the share of Punjab in the total industrial output is the highest. The table informs the readers about the provincial and overall losses both in volume and in percentages. Although the magnitude of losses varies in different scenarios, the percentage shares remain the same for provinces in all cases.

In the two dimensional analysis resulting in nine scenarios for each province, the lower limits of losses are Rs 132 billion, Rs 109 billion, Rs 17 billion and Rs 11 billion for Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan respectively. The upper limit of losses for

Punjab, Sindh, and Khyber Pakhtunkhwa are 400; 331; 54 and 34 billion rupees respectively. The overall industrial sector loss ranges between 269 and 819 billion rupees which obviously is an enormous cost to the economy in general and industrial sector in particular.

In the country-wide analysis, it is the food and beverages industry that endured most; while textile and chemical product industries are the second and third most affected industries respectively. In terms of the most affected province, Punjab tops the list with 49 percent share in total production loss due to unserved energy as is evident from Table 9.

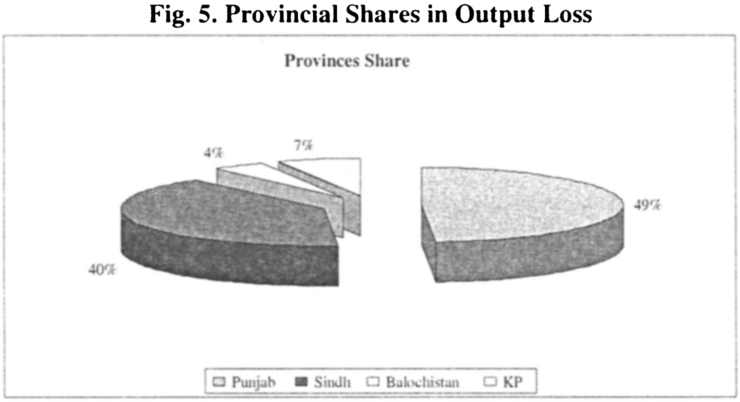
Table 9

Province-wise and Overall Output Losses (Billion Rs)

Province/Country	Shift Hours	AL	9 ML	6 ML	Percentage
	12	266.971	197.484	131.656	
Punjab	10	320.363	236.981	157.988	49%
	8	400.454	296.227	197.484	
	12	220.556	163.15	108.768	
Sindh	10	264.668	195.781	130.521	40%
	8	330.833	244.725	163.15	
	12	36.135	26.729	17.821	
Khyber Pakhtunkhwa	10	43.361	32.077	21.385	7%
	8	54.201	40.094	26.729	
	12	22.477	16.626	11.083	
Balochistan	10	26.972	19.951	13.3	4%
	8	33.713	24.939	16.626	
	12	546.139	403.989	269.328	
Pakistan	10	655.364	484.79	323.194	100%
	8	819.201	605.985	403.989	

Figure 4 demonstrates the provincial shares in output loss for visual convenience of the readers. It is obvious that Punjab is the major contributor to the production loss resulting from unserved energy. Sindh also faces the blow with 40 percent contribution while Khyber Pakhtunkhwa and Balochistan chip in with 7 percent and 4 percent contributions respectively. Hence, the energy crisis that started in 2007 has affected the industrial sector throughout the country. The loss, as a percentage of value added, of the overall industrial sector ranges between the limits of 12 percent and 37 percent. This range also covers the figure of 25.6 percent obtained by the Lahore Chamber of Commerce and Industry (LCCI) for Punjab due to the crises in 1984-85.

Fig. 5. Provincial Shares in Output Loss



6. CONCLUDING REMARKS

The study intended to show what the electricity shortfall cost to the industrial sector in Pakistan in terms of unserved energy. For this purpose, a survey was conducted in four major industrial cities of the Punjab to investigate the areas affected due to power outages. Ten industrial categories were formulated for in-depth analysis. Furthermore, nine different scenarios were assumed for each industry to cover for differences in shift hours and duration of outages during the year. Along with other aspects, the output losses were estimated for all industries. These estimates were then used for other provinces and for the overall industrial sector of the country.

The survey results, based on the responses of firms, reveal that labour hours have been affected due to outages, even so, most of the firms did not layoff labour due to labour hours loss. One reason may be that the majority of firms opted for alternative energy arrangements in the form of standby generators; mostly imported. This, on the one hand, increased their cost of production, and on the other, raised the import bill for the country. Furthermore, electricity shortfall also delayed meeting supply commitments. Since most of these industries also work in the export sector, this tarnished the image of the industrial sector both domestically and abroad that may ultimately reflect in reduced foreign exchange earnings. The study also tried to quantify the output loss of the industrial sector by making use of both survey data and data from CMI (2005-06). It is found that major affected industries in terms of volume of losses vary across provinces. However, in terms of percentages, the pottery and ceramic industry is the industry that suffered the most. In the overall analysis, food and beverages, textile, and chemical product industries are respectively the top three industries on the scale of losses. Lastly, the provincial share of 49 percent in total output loss makes Punjab the major affected province with Sindh behind. Overall, the industrial sector encountered, on average, a loss of 22.36 percent of value added due to unserved energy. The two dimensional analysis of output quantification suggests that the firms can reduce the loss by increasing the shift hours. The policy makers in power sector can achieve the same objective by appropriate load management policies that could reduce outage duration during the year. For this purpose, priority in maintaining the power supply should be given to those industries that are more energy intensive and have higher shares in the total industrial output. Furthermore, the gap between demand and supply can be significantly reduced by lowering transmission and distribution losses as it accounts for approximately 21 percent of net system energy.

This baseline study also brings forth some potential areas for future research. Since the current study quantify the cost based on idle factor only, the future studies should incorporate other costs also, such as spoilage cost, overtime cost, and adjustment cost. Furthermore, the studies should also explore the extent of the increase in production cost that is transferred to consumers and how much of it, if any, to labour in the form of real wage reduction. It should also be investigated if labour unions play any role or not in preventing the layoffs during energy shortfall. It will also be interesting to examine whether resort to alternative energy arrangements is sustainable in the long-term as it has been almost three years now since the crises started in the country. In addition, another cost of unserved energy in the form of dislocation (outflow) of investment to foreign countries can also be inspected. Moreover, since this study uses the percentages of

Punjab for other province based on some assumptions, a country-wide survey could be conducted covering all provinces and that should also examine the impact of unserved energy on households in addition to the industrial sector. Last but not the least, the linkage between trade and energy shortages may also be explored in future analyses.

Appendices

Table I

Summary Statistics for Labour Hour Loss per Day Due to Energy Shortage

Industry Group	Mean	Maximum	Minimum
Food Manufacturing and Beverages Industries	3.49	12	0
Manufacturing of Textiles	3.58	9	0
Leather and Leather Products	2.11	4	0
Wood and Furniture Products	3.92	9	0
Paper, Printing and Publishing Industries	0.50	1	0
Industrial Chemical and Other By-product Industries	2.82	8	0
Rubber and Plastic Product industries	3.64	12	0
Pottery, Glass, Chinaware and Ceramics Industries	4.42	12	0
Iron, Metal and Steel Industries	2.90	7	0
Electrical and Non-electrical Machinery Industries	3.41	10	0
Mean	**3.44**		

Table II

Tests of Independence (Chi-square Tests)

Variables	Test Statistics	Probability
Load Shedding-Labour Demand Reduction	549.055	0.000
Load Shedding-Supply Order Delays	98.544	0.000
Load Shedding-Production Loss	1785.503	0.000

Table III

Origin of Generator by Industry

Industry Group	Local	Imported	Firms
Food and Beverages	35.5	64.5	31
Textiles	17.3	82.7	52
Leather and Products	15.8	84.2	19
Wood and Furniture	23.1	76.9	13
Paper and Products	–	100.0	02
Industrial Products	12.5	87.5	08
Rubber and Plastic	33.3	66.7	18
Potter and Ceramic	16.7	83.3	18
Iron and Metal	44.4	55.6	18
Machinery (E & NE)	26.9	73.1	52
Mean % (Total N)	**25.1(58)**	**74.9(173)**	**100(231)**

Table IV

Average Increase in Cost of Production by Industry

Industry Group	Mean (%)
Food Manufacturing and Beverages Industries	34.38
Manufacturing of Textiles	30.09
Leather and Leather Products	26.81
Wood and Furniture Products	35.08
Paper, Printing and Publishing Industries	09.00
Industrial Chemical and Other By-product industries	43.50
Rubber and Plastic Product Industries	11.23
Pottery, Glass, Chinaware and Ceramics Industries	13.33
Iron, Metal and Steel Industries	37.12
Electrical and Non-electrical Machinery Industries	21.98
Mean (%)	**26.57**

Table V

Production Loss per Day by Industry Due to Unserved Energy

Industry Group	No loss	Less than 5 Percent	Between 5 to 10 Percent	Between 10 to 20 Percent	Between 20 to 40 Percent	Between 40 to 80 Percent	Above 80 Percent	Firms
Food and Beverages	47.6	04.8	09.5	19.0	14.3	04.8	–	42
Textiles	33.3	06.4	03.8	10.3	33.3	11.5	1.3	78
Leather and Products	25.0	15.0	15.0	05.0	20.0	20.0	–	20
Wood and Furniture	18.2	09.1	–	36.4	–	36.4	–	11
Paper and Products	100.0	–	–	–	–	–	–	01
Industrial Products	30.0	–	–	20.0	30.0	20.0	–	10
Rubber and Plastic	31.3	18.8	–	12.5	18.8	18.8	–	16
Potter and Ceramic	29.2	04.2	12.5	08.3	12.5	33.3	–	24
Iron and Metal	25.0	05.0	–	15.0	35.0	20.0	–	20
Machinery (E & NE)	17.5	07.0	17.5	10.5	21.1	26.3	–	57
Mean % (Total N)	**30.1(84)**	**7.2(20)**	**8.2(23)**	**12.9(36)**	**22.9(64)**	**18.3(51)**	**0.4(1)**	**100 (279)**

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