IMPACT OF PAKISTAN POWER DISTRIBUTION LOAD DATA IMPROVEMENT PROJECT

MAY 22, 2014

PRODUCED BY:

USAID POWER DISTRIBUTION PROGRAM

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MAY 22, 2014

IRG, USAID contractor for the Power Distribution Program

House 23, Street 19, F-6/2

Islamabad, Pakistan

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ACRONYMS

AGC	Automatic Generator Control
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AT&C	Aggregate Technical and Commercial
BEI	Brand Equity Index
CAIDI	Customer Average Interruption Duration Index
CO2e	Carbon Dioxide Equivalent
CPP	Captive Power Producer
CPPA	Central Power Purchasing Agency
CR	Cash Recovery
CT	Current Transformer
DISCO	Distribution Company
FATA	Federally Administered Tribal Areas
FESCO	Faisalabad Electric Supply Company
FY	Financial Year
GDP	Gross Domestic Product
GEPCO	Gujranwala Electric Power Company
GOP	Government of Pakistan
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communications
GWh	Gegawatt-Hour
HBP	Hagler Bailly Pakistan (Pvt.) Ltd.

HDI	Human Development Index
HESCO	Hyderabad Electric Supply Company
Hz	Hertz
ICT	Information and Communications Technology
IESCO	Islamabad Electric Supply Company
IPPs	Independent Power Producers
IRG	International Resources Group Ltd.
IT	Information Technology
KESC	Karachi Electric Supply Company
KPI	Key Performance Indicator
kV	Kilovolt
kWh	Kilowatt-Hour
LDI	Load Data Improvement
LESCO	Lahore Electric Supply Company
LPG	Liquid Petroleum Gas
LSM	Large Scale Manufacturing
MDG	Millennium Development Goal
MDM	Meter Data Management
MEPCO	Multan Electric Power Company
MW	Megawatt
MWh	Megawatt-hour
NEPRA	National Electric Power Regulatory Authority
NOC	Network Operations Center
NPCC	National Power Control Centre

NTDC	National Transmission and Dispatch Company
O&M	Operations and Maintenance
PDC	Power Distribution Control
PDP	USAID Power Distribution Program
PESCO	Peshawar Electric Supply Company
PITC	Power Information Technology Company
PPP	Purchasing Power Parity
QESCO	Quetta Electric Supply Company
RCC	Regional Control Centre
SD	Standard Deviation
SEPCO	Sukkur Electric Power Company
SMS	Secured Metering System
SPP	Small Power Producer
t	Ton
T&D	Transmission and Distribution
TDS	Tariff Differential Subsidies
TESCO	Tribal Areas Electric Supply Company
TOU	Time of Use
u	annual per capita electricity consumption
UN	United Nations
UPS	Uninterruptible Power Supplies
USAID	United States Agency for International Development
WAPDA	Water and Power Development Authority

EXECUTIVE SUMMARY

In recent years, Pakistan has been struggling with severe power shortages leading to extensive electricity outages that have negatively impacted the economy[1]. The Government of Pakistan (GOP) has placed resolving the energy crises at the top of its economic agenda. It is keen to address shortfalls and constraints in all segments of the power sector, from generation to transmission and distribution, as well as to resolving the crippling circular debt. The USAID-funded Power Distribution Program (PDP) was designed to assist the GOP in achieving this objective through improving the performance and capacity of the electricity distribution system operated by the state-owned distribution companies (DISCOs). To improve management of the power sector and decrease the volume and frequency of unscheduled load shedding, USAID asked PDP to design and deliver the Load Data Improvement (LDI) project.

THE LDI INTERVENTION

The LDI project was designed to monitor network loads and power flows from the interface of the electricity distribution system operated by DISCOs and with the national power transmission grid operated by the National Transmission Dispatch Company (NTDC). The project includes the installation of digital automatic meter reading (AMR) devices at all power substations on the DISCOs' electricity grid so as to provide real time information on power flows into all grid stations (incomers) as well as power flows on all outgoing 11 kV feeders and 11 kV small and captive power producers (SPPs and CPPs) and 11 kV load flows between DISCOs. LDI hardware, including AMR meters, communication links, computer servers, information display panels, and custom-designed software and databases, provide detailed network operational performance and quality parameters on a near real-time basis to grid operators at the DISCO headquarters and NTDC control centers.

Prior to LDI, the national power system was being operated virtually 'in the blind' with only a frequency meter to alert operators of general grid imbalances and with no insight into specific DISCO loads and power draws from the national generation pool or into overloaded or malfunctioning feeders and transformers. All communications and instructions were conveyed manually leading to frequent over- or under-compensation, excessive forced outages, poor power quality, delayed and insufficient reporting, and slow response and remediation times.

[1] By one estimate, power outages cost Pakistan roughly Rs 1.4 trillion ($14.3 billion) in 2011-12.

The LDI-provided information represents a quantum jump in terms of data available to network operators for managing the national and regional electricity transmission and distribution system, providing constantly updated data down to individual feeder level on system demand, loads, dispatch, consumption, and quality attributes. With the advent of the wealth of accurate, high resolution network data provided by LDI, power dispatch and distribution functions are now greatly improved, unnecessary load shedding has decreased, power and service quality is enhanced, DISCO revenues and profitability have increased, and the national economic losses resulting from forced power interruptions have reduced. As such, LDI has directly contributed to improving the financial health of Pakistan's power sector, enhanced economic growth prospects, and is leading to a better-informed planning and investment process in support of the government's overall power sector reform objectives.

The original LDI project cost of $3.1 million was subsequently increased to $3.8 million as the scope of work was expanded to include the newly-created tenth DISCO (TESCO) as well as additional features to the project. This study concluded direct and indirect financial and economic gains resulting from the LDI project have greatly exceeded its cost, in addition to identifying a variety of immediate and longer-term qualitative benefits that further enhance its overall value and importance both for the power sector as well as Pakistan's economy as a whole.

LDI IMPACT ASSESSMENT

The report assesses the impact of the LDI project based on a comparison of actual grid performance data, since its commissioning in July 2013 to February 2014, with the corresponding period a year earlier (July 2012 to February 2013). Impacts have been evaluated at the national, power sector and utility levels, and have been quantified wherever possible. Additional potential benefits have also been discussed where LDI-enabled decisions and actions could result in more optimized policy and management practices aimed at expediting the sustained and efficient development of the country's power sector.

The following exhibit summarizes the major LDI-enabled impacts. For details please refer Section 3 (Direct Impacts), Section 4 (Indirect Impacts and Benefits) and Section 5 (Additional Future Benefits) of this report.

Exhibit E.1: Summary Impacts

LDI-Enabled Impact /Action	Output	Outcome
Load Shedding		
• Improved insight into DISCO loads and demand profiles	• More accurate load shedding planning	• Decline in unscheduled load shedding by 85% • Shift of 200 MW of unscheduled load shedding to scheduled load shedding
Utility & Power Sector		
• Optimization of DISCO power allocations by NTDC	• Reallocation of underutilized power quotas from underperforming DISCOs to better performing DISCOs	• Projected annual increase in sales revenue of $62.3 million annually by selling more power to better performing DISCOs • Reallocation of 3,072 GWh per year to better performing DISCOs • Improved productive use of electricity and reduced energy intensity per unit GDP
• Greater visibility into network operations	• Improved utility practices, including economic dispatch based on losses and collections • Better system maintenance • Greater transparency and accountability in utility practices	• Reduction in technical and non-technical losses by up to 0.5% in better performing DISCOs • Reduced overloading of grid components and resulting damage • Improved service delivery and customer satisfaction
Power Quality		
• Better management of grid system supply-demand imbalances	• Improved system frequency coherence and stability • Better system compliance with regulatory standards	• Reduced power infrastructure degradation and disruptions • Reduced end-use equipment damage and financial losses
Economic Performance		
• Shift of unscheduled load shedding to scheduled load shedding	• Electricity users can make appropriate adjustments and reduce damage and losses caused by unannounced outages	• Estimated annual total loss reduction of $180 million annually
Social Well-Being		
• Reduced unscheduled load shedding	• Reduced disruption of employment, income, healthcare, education, leisure opportunities	• Decreased poverty pressures • Improved social and quality of life indicators
• Dispatch optimization and reserve trimming	• More equitable load shedding	• Improved Human Development Index (HDI) levels, economic productivity, and GDP/capita
Long-Term Benefits		
• Optimized spinning reserves	• Potential increase in power dispatch from available generation assets	• Reduced load shedding • Improved HDI
• Independent metering of grid power flows and transfers	• Transparent and reliable accounting required for full operation of CPPA as transaction manager for power sales in country	• Improved competitiveness in power market and promotion of GOP reform agenda

1. INTRODUCTION

Pakistan's persistent power crisis, a function of increasing demand, insufficient generation capacity interventions and a faulty transmission system, has resulted in nationwide electricity shortages. These shortfalls have progressively worsened over the past 10 years with forced outages ("load shedding") reaching a peak of approximately 5,000 megawatts (MW)[2] during the summer months of 2010-11. The shortages translated into power outages of up to 20 hours a day in many rural areas and from 8 to 10 hours in urban areas—their predictability having been hampered by a manually operated grid load management strategy that relied on inadequate system load monitoring capability, subpar communication links and manual computation and documentation systems at the distribution companies (DISCOs) and the National Transmission and Dispatch Company (NTDC).

The resultant lack of accurate real-time grid performance data led to suboptimal generation capacity utilization and power dispatch practices, which further aggravated the power crisis and its resultant socio-economic impacts. Sector-wide power related issues, coupled with imprecise quantitative information pertaining to Pakistan's power grid, hampered efficient power distribution operations and resulted in additional unplanned power outages beyond the "scheduled" load shedding; accentuating economic damage and causing social disruptions at a time when the country's economy was already struggling to emerge from a protracted period of sluggish growth.

Higher retail electricity tariffs resulting from the withdrawal of unsustainable levels of consumer subsides (as part of overall power sector reforms) coupled with intermittent and unreliable power supplies have resulted in a loud outcry from the media and general public. Tired of extended blackouts across the country, in 2012 many took to the streets to let their complaints be known. With large number of industrial units severely affected by the lack of reliable electricity supplies (many had to curtail operations or even shut down) unemployment increased, incomes fell, and total exports dropped. Social services, such as health and education, and small businesses were equally impacted, and poverty pressures increased. The resulting loss of incomes, jobs, and chronic disruption of normal daily lives led even ordinary citizens to take to the streets to demand an end to load shedding. Protests against persistent and prolonged power outages by various consumer groups—especially during the hot summer months—often brought large parts of major cities to a standstill and frequently turned violent, oftentimes causing serious injury and even loss of life. At a minimum, such demonstrations caused extensive damage to public and private property and disrupted business and commercial activity. This situation was the most visible manifestation of the untenable state that the power sector had reached, facing huge supply-

[2] This is the supply-demand gap as recognized by the Government of Pakistan. In reality the gap at times exceeds 9,000 MWs.

demand gaps and hobbled by a crippling circular debt that prevented it from implementing any immediate or long-term remedies and investments. As a result, the national power system seemed to be locked in a downward spiral, with load shedding increasing every year as demand continued to rise and generation capacity additions and transmission and distribution (T&D) improvements failed to materialize.

The damage to the national economy of the power shortages and intermittent supplies has been substantial. A recent comprehensive study[3] estimated the direct and indirect costs of load shedding to Pakistan's economy at a staggering Rs. 1.4 trillion ($14.3 billion) in 2011-12, or 7% of the national Gross Domestic Product (GDP)[4]. Inadequate access to electricity has undermined Pakistan's aim of achieving the United Nations (UN) Millennium Development Goals—aimed at reducing by half, the population currently living at or below poverty levels—a goal the Government of Pakistan (GOP) had pledged to attain by 2015, some of which now seem unlikely to be met. The national energy situation continues to be a major source of concern for the GOP, international development partners, and other stakeholders in the Pakistani power sector, resulting in forensic studies being conducted to identify possible solutions and mitigating actions being prioritized for implementation across all areas of electricity generation, transmission and distribution.

The United States Agency for International Development (USAID) has earmarked a substantial portion of its economic assistance to Pakistan for expanding generation capacity, improving distribution efficiencies, and supporting reform of the country's energy sector. This multi-pronged approach aims to address immediate energy shortages while helping the country build longer-term energy security. Under the five-year, $230 million USAID-funded Power Distribution Program (PDP), technical and financial assistance has been provided with the goal of improving operational and financial performance of GOP-owned DISCOs[5] in order to bring them at par with well-run utilities elsewhere in the world. PDP also works with the Ministry of Water and Power and the National Electric Power Regulatory Authority (NEPRA) to improve governance, regulatory frameworks, and management of the power sector. The PDP-delivered Load Data Improvement (LDI) Project is an important element of USAID's overall effort dedicated to improving the management and quality of electricity distribution services across Pakistan.

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[3] Pasha [2013].

[4] Including a loss in exports of 14% ($3.5 billion) and an increase of 1.8 million in the unemployed population.

[5] Originally nine DISCOs (FESCO, GEPCO, HESCO, IESCO, LESCO, MEPCO, PESCO, QESCO, and SEPCO) were targeted under PDP for participation in the LDI project. This was expanded to a tenth DISCO with the formation of TESCO.

1.1. ORIGIN AND SCOPE OF THE LOAD DATA IMPROVEMENT PROJECT

In Pakistan, national and DISCO-level power dispatch control has traditionally been carried out using very rudimentary methods. Using dated and highly unreliable data, systems managers would have to make decisions with little or no knowledge of the current operational situation from generators or end users. Loads were assessed by control center operators primarily, based on historical data that had been manually recorded, and instantaneous supply-demand system imbalances were inferred roughly on the basis of simple voltage frequency meters installed at the control centers (**Exhibit 1.1**). Controllers had no access to accurate real-time information on grid performance, loads, or status of individual lines, transformers, and served demand, and were unable to differentiate between planned outages, system faults, and maintenance shutdowns. Depending largely on verbal communications and based on a rough assessment of estimated available capacities and demand at any given time and the operator's experience, management actions were carried out largely in reactive, rather than predictive manner. As a result, dispatch controllers were forced to make conservative allocations to DISCOs, holding significant amounts of generation to meet unforeseen peaks. Reaction times to dynamic load and generation changes were slow requiring utilities to resort to frequent forced or unplanned outages that greatly degraded the supply of electricity to consumers in terms of quality, reliability, and predictability. Tripping of overloaded transmission lines, degradation of transformers, and substation breakdowns resulting from poor network control were a common feature which further exacerbated the situation. The economic and social consequences of such deficient grid management practices added to the already severe impact of overall generation capacity shortfalls. They further reduced customer satisfaction, willingness to pay and, therefore, revenue collection by DISCOs, while at the same time increasing DISCO system maintenance costs due to the wear and tear wrought by load imbalances and startup fluctuations on network assets, as well as frequent switching on and off of the distribution grid control equipment.

Exhibit 1.1: Frequency Meter Used for Grid Balancing Prior to LDI Implementation

In order to help manage load shedding better, a project was conceived in 2012 to track and monitor in near real-time, the load and the status of 11 kV circuit breakers at each of the DISCOs grid substations. The project envisaged the installation of automatic meter reading (AMR) devices, with an accuracy of 1%, across DISCO networks, with data flow between planned metering nodes and data collection and storage facilities taking place through commercial cellular general packet radio services (GPRS).

The original scope was later expanded to include additional load monitoring, system management, and communications and data reporting features. These improvements ultimately resulted in the creation of a greatly enhanced and integrated national power distribution control and coordination tool capable of providing DISCOs and the National Power Control Centre (NPCC) access to accurate, near real-time information from the substation/feeders. Such information is pertinent not just for satisfying the original aim of effective load shedding management by the DISCOs, but has enabled a quantum jump in improving operational monitoring, control, and system optimization by both the distribution utilities and the national grid operator. In addition, it has allowed for enhancing the productive use of available generation capacity and planning of long-term grid investments.

The LDI project—whose original objective was to reduce the amount of unplanned load shedding in the country through the use of real-time data—has far exceeded expectations. The project has made a significant, concrete impact on reducing unscheduled outages while optimizing use of power available for dispatch at any given time. The system allows for improved governance of day-to-day operations while also providing a treasure trove of data useful in policy development which, as this report points out, will be essential for addressing key, long-term power sector reform objectives.

1.2. LOAD DATA IMPROVEMENT PROJECT OBJECTIVES

The objectives of the LDI project were to assist the GOP in reducing incidents of unplanned load shedding and reduce the buffer generation capacity (spinning reserve) kept by the NPCC in order to cater for load swings. It would thus improve the utilization of available generation capacity, and allow the national grid and distribution utilities to obtain more accurate information in real-time on their load demand and servicing requirements.

It was also designed to impart a greater degree of transparency and accountability in utility operations, help reduce political interference and corrupt practices, and improve operational and management controls over utility performance. By providing accurate archival data, it would enable utilities to better understand their customer load profiles and more accurately account for daily and seasonal demand variations, as well as monitor system imbalances for preemptive action and maintenance. Another important objective was to enable DISCOs to improve service

delivery and customer satisfaction by improving reliability of power supply and predictability of load shedding, as well as to improve tariff recovery and sales revenues by prioritizing service delivery to paying customers. As a result of these improvements, DISCOs would be expected to accrue savings on account of reduction in operations and maintenance (O&M) costs incurred on overloaded or high-loss feeders and transformers, and transition from a "firefighting" mode of network maintenance to one of "preventive" maintenance with greater resource and information availability and transparency for proper planning of future investment and expansion needs.

The LDI project, along with the Secured Metering System (SMS), once operational, will provide an essential element of the overall power system metering and accounting mechanism required for enhanced grid management at the national level, including the planned transition to an open power trading market in Pakistan with a fully autonomous Central Power Purchasing Agency (CPPA).

1.3. PROJECT DESCRIPTION

The LDI project, launched by USAID in December 2012, envisaged the installation of static digital AMRs (Class 1, with a stated accuracy of 0.5%) at all power substations on the country's national electricity grid[6] belonging to nine DISCOs[7] (excluding the feeders of, but including the 132 kV grid interconnection with, K-Electric—the utility serving the Karachi metropolitan and adjoining regions). The system was designed to monitor power flows through current transformer (CT) coils mounted on all outgoing 11 kV feeders and transformer breaker panels for incoming current, as well as the incomers of 132 kV industrial (B4/C3) connections and 11 kV small and captive power producers (SPPs and CPPs). The meters are installed in conjunction with existing utility metering, on frames above the switchgear (**Exhibit 1.2**).

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[6] The national power grid consists of transmission lines of 220 kV and above and distribution networks of 132 kV and below, not including standalone regional 132 kV networks, such as that serving the Makran region.

[7] FESCO, GEPCO, HESCO, IESCO, LESCO, MEPCO, PESCO, QESCO and SEPCO.

Exhibit 1.2: Bank of LDI AMR Meters Under Testing

Load measurements taken continuously at a preprogrammed frequency[8] by each automated meter and other operational parameters are communicated wirelessly over the GPRS/Global System for Mobile Communications (GSM) cellular telephony network to a central Network Operations Center (NOC) based in Lahore. The NOC includes four Hewlett Packard Blade data servers and one dedicated meter data collection server[9] for each DISCO, which process and store all data for onwards transmission to the relevant DISCO Power Distribution Control (PDC) centers via dedicated routers and secure web links on leased fiber optic connections. PDC centers are set up at each DISCO headquarters and equipped with necessary computers and screens, to record and display all relevant incoming information near real-time through customized simplified meter data management (MDM) software. The locally developed software provides both real-time and archival[10] information on the distribution networks' status and performance which is used for both improved operational control and increased management oversight of the network.

Aggregated data are dispatched directly from the NOC over secure fiber optic links to the NPCC control room in Islamabad, where the NPCC uses the information to monitor an individual DISCO's power consumption compared to allocated ceilings, and overall consumption as compared to total generation. LDI provides information on specifically tailored display interfaces installed at the NPCC to augment their existing information system screens. All grid performance data are stored on the NOC servers, with relevant subsets of data also stored on LDI computer

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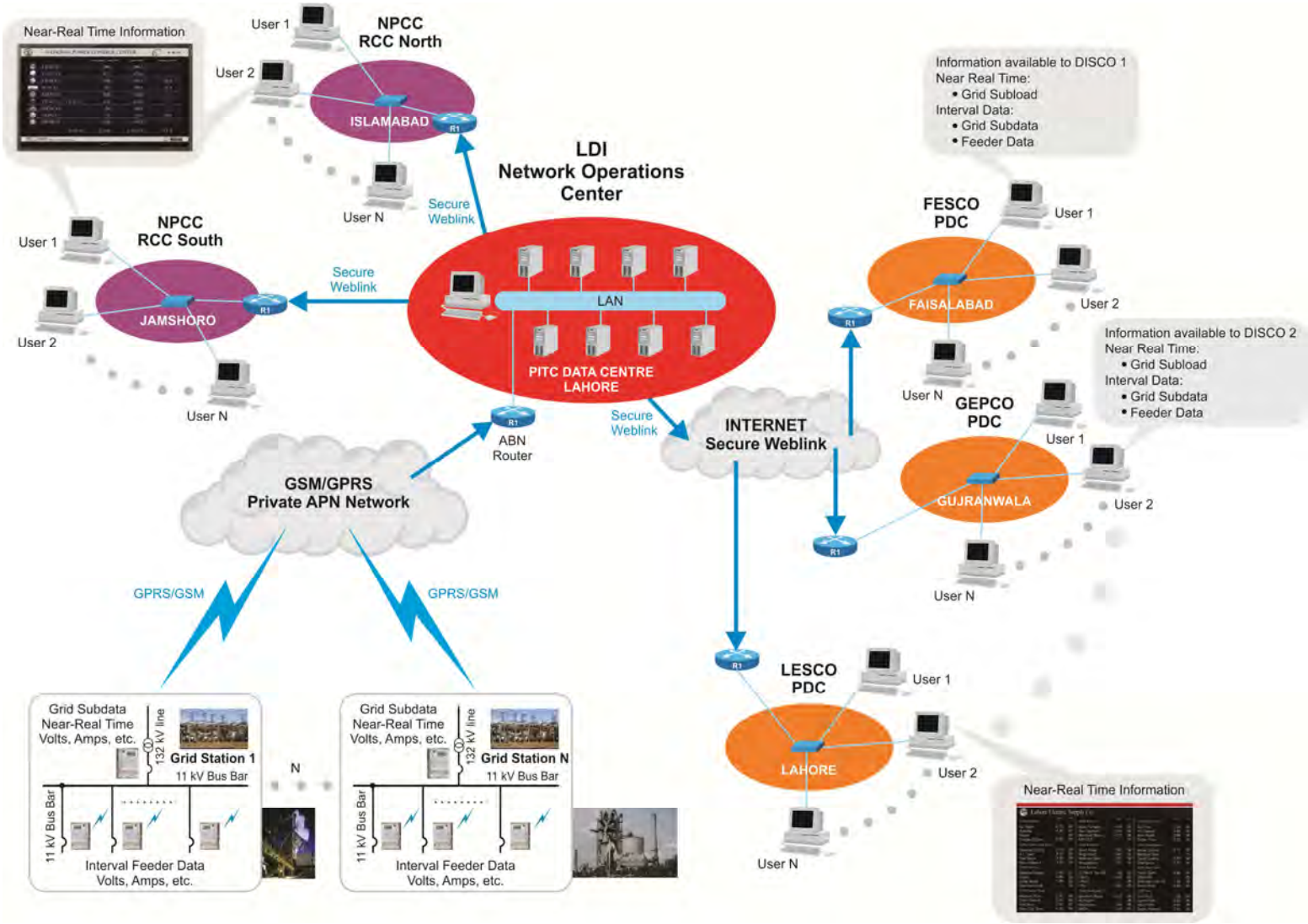
8 'Always live' AMR devices installed at incoming feeders are grouped into intervals (of 10 second pool over 1 minute complete cycle) for the purpose of data transmission to ensure uniform and manageable levels of data flow. AMR meters installed at outgoing feeders report at a 15-minute interval, while 'live' events, i.e., the switching on and off of feeders, are reported instantaneously.

9 The meter data collection server is dedicated to data communications and to writing all relayed meter information to a central database.

10 Stored at 15-minute intervals.

servers at the NPCC and each DISCO. This allows DISCOs' senior managements to query data at any time for subsequent accounting, analysis and planning purposes. A schematic configuration of the LDI system is shown in **Exhibit 1.3**.

Exhibit 1.3: LDI System Configuration



Three different software packages corresponding to different tiers of metering data collection, management, and information dissemination were developed for the LDI project. The Smart Eye meter monitoring and management system, remotely communicating with arrays of AMR meters installed across the country, obtains a variety of consumption data and then stores them in a centralized database. The software utilizes GPRS as a communication channel and DLMS/COSEM as the communication protocol. The system allows the operators at the PDC centers and NPCC to access and further analyze the real-time metering data managed and processed by the Smart Eye system. The software has a graphical user interface, is accessible via the Internet, allows for the generation of graphical and tabular reports, and comes with a multi-hierarchical user management system with differentiated administrative rights. LiveView modules installed at PDC centers display real-time grid station load information on the "operators" LCD panels (Error! Not a valid bookmark self-reference.) as well as summarized and segmented data by consumption categories on the "executive" screens provided only to DISCOs' senior managements (

Exhibit 1.5). At the NPCC, the software module displays summary statistics for each individual DISCO's load (

Exhibit 1.6). The LiveView interface has been structured in a manner to allow visibility to operators present in a large control center.

The original scope of the LDI project included the supply of 10,199 AMR meters; 7,845 meters for installation on the national grid and 2,354 meters to serve as operational backup. Later the contract was modified to include an additional 1,200[11] meters, increasing the total number of meters procured to 11,399 AMR of which 9,045 were installed and 2,354 meters held in reserve as operational backup. In addition, the LDI project commissioned PDC Centers at all 10 DISCOs, established the NOC in Lahore, and installed data display screens at the NPCC. PDP procured equipment including computer servers, multiple flat panel display screens and furniture for each center and contracted bandwidth services for three years for each DISCO region; renovation of PDC spaces; and the development, delivery and training on various aspects of data display, management, and reporting and software features.

[11] The increase was to cover auxiliary feeders not originally envisioned under the project as well as expansion to the TESCO service territory.

A subsequent expansion of the LDI scope of work included the supply and installation of an additional 2,354 AMR meters as well as supplemental computers, display screens, communications equipment, printers, and ancillary hardware, as well as setting up a fully-equipped PDC center at Tribal Electric Supply Company (TESCO) (a new DISCO formed in 2013 and serving the Federally Administered Tribal Area (FATA) region) and its associated data communications costs for three years. The NPCC recently licensed a Regional Control Center (RCC) to be located at Jamshoro, focusing on the southern grid region, while the existing center in Islamabad now acts as the RCC only for the northern region. The LDI setup at NPCC in Islamabad is being duplicated at the Jamshoro RCC for this purpose. Project interventions are also being designed to monitor consumption behavior of large industrial and commercial consumers. An LDI disaster recovery center has been separately set up in Lahore to provide necessary redundancy for NOC operations.

A breakdown of the overall cost of the LDI project is given in **Exhibit 1.7**.

Exhibit 1.4: LDI LiveView Operator Displays at DISCO PDC Center

Lahore Electric Supply Co. — Watch List

	MW	%PF
132KV Attabad		
Ali Paper	6.15	95
Ayesha	4.30	97
Rupali	[illegible]	90
Punjab Cotton	6.85	95
132KV Allama Iqbal Town		
Wahdat Colony	5.15	89
A.I. Town	8.12	92
Pak Block	4.35	99
Moon Market	3.85	95
132KV Ayesha		
Mujahid Nagar	3.65	97
Royal	4.86	92
Zafar Abad	1.99	90
New Industrial	[illegible]	95
132KV Badami Bagh		
Wassan Pura	2.87	89
Dehli Gate-III	3.15	85
Fort No.II	2.00	87
New City Steel	4.85	96

	MW	%PF
132KV Bata Pur		
Iqbal Furnace	4.56	85
Ravi Syphon	2.85	89
Mandian Wala	6.12	98
KAY-CEE	[illegible]	93
132KV Bhogiwal		
Bund Road	3.85	90
Ring Road	6.45	95
Rehman Steel	2.97	99
Bhagatpura	3.65	90
132KV Bucheki		
G.T.Mill(F No.10)	1.50	85
F.No.5	4.20	80
F.No.6	[illegible]	98
F.No.7	6.85	93
132KV Bhatti Gate		
Ibarahim Road	6.12	90
Ali Hajveri	[illegible]	98
Kasurpura	3.86	89
WASA	5.00	100

	MW	%PF
132KV Chah Miran		
Taj Pura	5.18	85
K.K.Saeed	4.85	80
Amir Road	2.98	98
Sultan Pura	3.50	92
132KV Daroghawala		
Akbar Colony	3.15	85
Murtaza Steel	[illegible]	75
Daud Colony	2.85	98
Sharifpura	3.26	95
132KV Fateh Garh		
Fateh Garh	3.96	90
Ghee Mill	[illegible]	95
Shalimar Link Rd.	1.98	99
Bund Road	2.85	85
132KV Fort		
Fort No.2	1.98	100
Karim Park	3.65	98
Iqbal Park	4.65	89
Bazar Hakima	2.85	93

Exhibit 1.5: LDI LiveView Executive Display at DISCO PDC Center

Exhibit 1.6: LDI LiveView Display at NPCC

NATIONAL POWER CONTROL CENTER 16 : 23 : 09

	Demand - MW	Allocated - MW	Drawn - MW	Variance - MW
LESCO	3,027	2,242	2,435	193
GEPCO	1,523	954	976	22
FESCO	2,319	1,281	1,359	78
IESCO	1,557	1,068	1,180	112
MEPCO	2,858	1,602	1,637	35
PESCO + TESCO		1,708	1,301	-407
HESCO	1,295	694	600	-95
SEPCO	1,038	587	546	-41
QESCO		641	375	-266
TOTAL		10,777	10,408	-369

USAID POWER DISTRIBUTION PROGRAM

Exhibit 1.7: Breakdown of Original and Modified LDI Project Costs

Original Scope of Work	Cost (Rs)	Cost ($)
Supply & commissioning of meters	188,236,549	1,901,379
Meter data collection computer equipment	5,431,034	54,859
PDP data center equipment supply, installation and commissioning	30,517,236	308,255
Upgrades for nine PDC centers	29,250,000	295,455
Other expenses	56,322,301	568,912
Original Total	309,757,120	3,128,860
Additional Scope of Work	**Cost (Rs)**	**Cost ($)**
Miscellaneous communication equipment	14,231,000	143,747
Miscellaneous computer equipment	3,215,350	32,478
Upgrades for TESCO PDC and data equipment	7,953,738	80,341
Additional AMR meters and communication services	39,544,846	399,443
Additional Cost	64,944,934	656,009
Total Project Cost	374,702,054	3,784,869

1.4. PROJECT TIMELINE

Following preliminary project due diligence, the LDI project scope went through a detailed design and costing review within PDP, and negotiations and discussions were conducted with Power Information Technology Company (PITC) and DISCOs to finalize the technical details of project implementation. Project outcomes were agreed upon, and specific activities and procurement needs were conceived, planned and segmented in order to achieve them.

The LDI project was approved for delivery by USAID with execution starting in December 2012. The original project implementation schedule, consisting of activities ranging from project due diligence to LDI system commissioning at the NPCC and the DISCOs and its eventual handover to them, was spread over 11 months, as shown in Error! Not a valid bookmark self-reference..

After finalization of hardware specifications, procurement of project equipment was initiated in February 2013, and the first set of AMR meters was installed in the same month. By early July, PDP had successful installed and made operational (including active communications links to the NOC) 82.5% of all AMR meters planned for installation nationwide. Information coming from the LDI system was sufficient to be of benefit to the NPCC in their load flow management efforts; therefore, the LDI data screen was made live on July 9, 2013. Installation of remaining meters continued after the system had been made operational, and is now linked with NTDC's SMS project on the outgoing 132 kV lines to K-Electric. This enables LDI to monitor inter-grid transfers to K-Electric.

The geographical location of the LDI metering system is illustrated in **Exhibit 1.9.**

Exhibit 1.8: Schedule of Activities Under Original LDI Project Scope

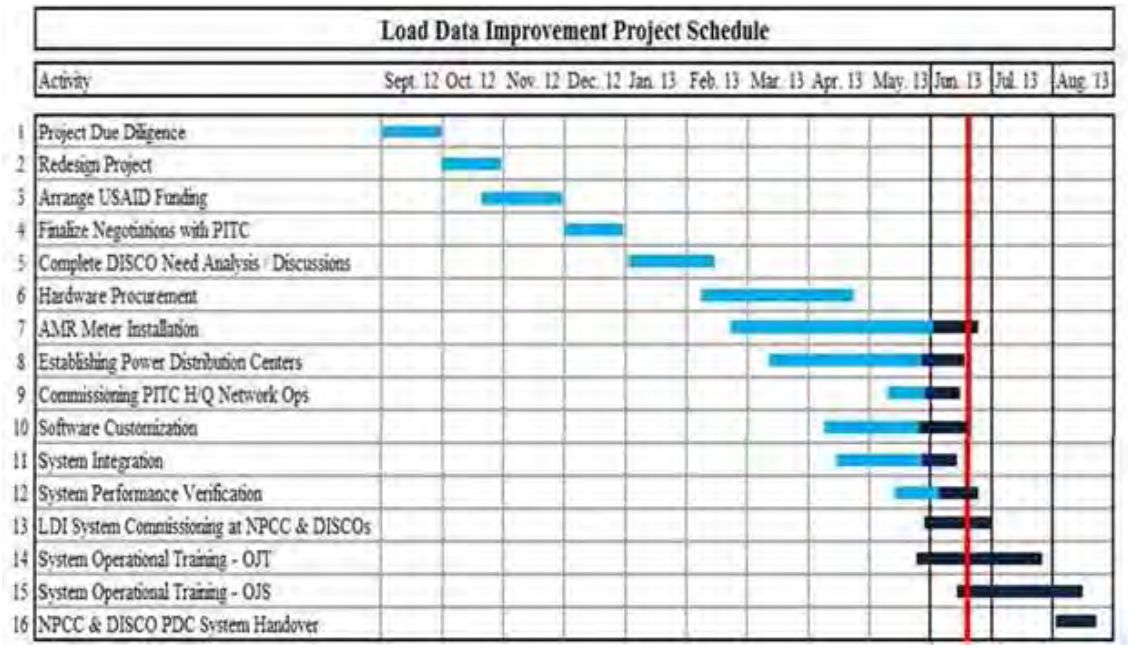
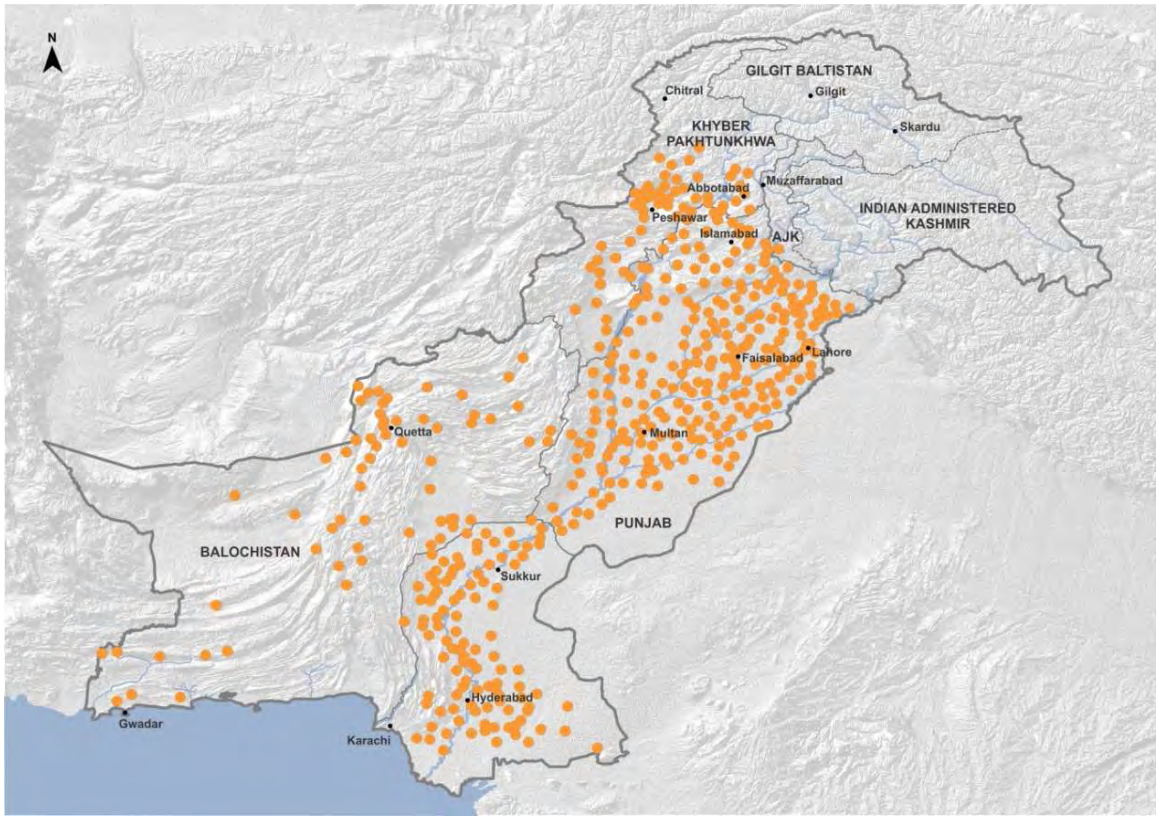


Exhibit 1.9: Geographical Location of LDI AMR Meter Installations



A contract modification for additional activities to be executed under the LDI project, mentioned above, was issued on January 15, 2014, under which AMR meters are to be installed on the 11 kV feeders of TESCO and a PDC center established.

As of February 28, 2014, meter installation targets planned during the original and extended scope of work have been accomplished at Lahore Electric Supply Company (LESCO), Gujranwala Electric Power Company (GEPCO), Faisalabad Electric Supply Company (FESCO), Multan Electric Power Company (MEPCO), Hyderabad Electric Supply Company (HESCO), and Sukkur Electric Power Company (SEPCO). Up to 97% and 98% of the aforementioned targets have been achieved at PESCO and IESCO, respectively, whereas at QESCO the corresponding figure is 90%. Project implementation has been initiated at TESCO as well. Further refinement of the Galaxy software and expansion of the LDI database to include information on energy flows, meter configuration, line metering[12], power quality monitoring[13], additional reporting functions etc. are also currently underway. A "field performance evaluation" is currently being conducted at various DISCOs to identify and correct anomalies in meter and CT installation through systematic inspections. Meter GPRS communications have also been made independent of the cellular operator to make better use of the full national coverage capabilities and relative signal strengths of all cellular service providers in Pakistan.

The status of the LDI AMR installation at each DISCO network as of end-February 2013 is shown in **Exhibit 1.10.**

[12] Estimation of power flows through parts of the grid located in remote areas with poor or nonexistent communication links (i.e., GPRS/GSM) using mathematical algorithms to determine load throughput. Line metering is being implemented in QESCO and TESCO regions, where it is a significant need.

[13] For grid stability and distribution planning purposes, including alerts such as peak and seasonal loads, feeder/transformer loading, power factor, bus voltage, etc.

Exhibit 1.10: Status of LDI AMR Installation as of February 28, 2014

Scope of Work			Extended Scope (Approx.)	Total Meters	Installation Status* as of February 28, 2014				Percentage Completion*
s	O/G Meters	Total Meters			No. of Grids	I/C Meters	O/G Meters	Total Meters*	
	762	908	145	1,053	85	203	855	1,058	100%
	643	754	76	830	53	145	688	833	100%
	371	468	96	564	72	123	442	565	100%
	799	976	140	1,116	79	202	893	1,095	98%
	1,308	1,540	140	1680	99	292	1,396	1,688	100%
	901	1,102	146	1,248	116	245	1,009	1,254	100%
	749	921	120	1,041	87	232	777	1,009	97%
	445	557	157	714	71	126	517	643	90%
	380	465	87	552	60	109	445	554	100%
	125	154	93	247	1	2	18	20	8%
2	**6,483**	**7,845**	**1,200**	**9,045**	**723**	**1,679**	**7,040**	**8,719**	**96.4%**

DI scope.

ters installed at the 11 kV side of 132/11 kV transformers at grid stations to record power received at the grid station.

stalled at 11 kV feeder panels to record power delivered to a feeder.

2. STUDY METHODOLOGY

2.1. IMPACT ANALYSIS

Based on the performance of the power grid during comparable periods prior and subsequent to the implementation of the LDI project and existing studies on the potential impact of power outages, a sector-wide evaluation of the impact of the project on the overall power supply situation can be derived. In the absence of detailed pre- and post-LDI field surveys of affected stakeholders, a first approximation of the impact of LDI-based improvements on Pakistan's national economy can also be made in the context of the current power supply-demand regime. Financial and operational gains to the power utilities resulting from enhanced LDI-enabled system monitoring and control can be similarly identified. Finally, qualitative assessments can be made about the potential future benefits of the LDI facility on the power sector as a whole, which would also have strong economic connotations for the country.

While it is not possible to elaborate on the complete methodology followed in each of the previous national and sector impact assessments (i.e., those listed in

Exhibit 4.1 and **Exhibit 4.2**), relevant features are described briefly in **Section 4.1** and further details can be obtained from the studies themselves listed in the **References** section at the end of this report. These studies enumerate the various factors that affect the normal economic output of a sector (industry, agriculture, commerce, etc.) by identifying specific impacts of power outages (e.g., lost production time, spoilage, unemployment, etc.) that, in turn, influence various relevant economic and social aspects (value addition, costs, incomes, productivity, etc.). Mathematical quantification methods can be formulated for many (but not all) such impacts and, based on a representative sampling of respective sectors through surveys of affected entities and end users, values are derived for use in such formulations to arrive at, for instance, the economic cost per unit of power outage in each case. Extrapolating these factors to the national level provides a useful estimate of the overall cost of electricity outages for each sector and to the country as a whole. Additionally, studies on the relationship of electricity consumption to social and human development are used to obtain a rough quantification of the impact of power disruption on the well-being of the country's citizens and the attainment of reasonable levels of essential social indicators in education, health, incomes, etc.

Using these previous detailed estimates as a base, inferences and extrapolations have been drawn for a quick assessment of the LDI project's impact on the current power supply situation. These impacts entail two distinct parts:

2.1.1. DIRECT LDI IMPACTS

Evaluation of the immediate, direct impact of LDI on the incidence of grid performance and power delivery factors, such as the amount, duration, and frequency of load shedding, additional electrical energy made available to end-consumers through improvement in load and dispatch management (including possible reduction in spinning reserve requirements), optimization of utility revenue collection through better service delivery and feeder prioritization, and other primary factors can have potential downstream economic, social and other benefits. In this report, direct impacts of the LDI project on improved power system performance parameters have been evaluated through a comparison of recorded utility data provided for the national grid since the LDI became operational to date (i.e., July 2013 to February 2014) with the same months of the previous year without the LDI facility (i.e., July 2012 to February 2013) to allow a direct monthly comparison, implicitly accounting for seasonal variability. Utility financial (billing) information is only available on a financial year basis (the same as the calendar year) and therefore, financial performance comparisons have been made for the July-December period for both the pre- and post-LDI periods. Utility-level power system data (megawatts allocated, drawn, load demand, load shedding schedules, forced outages, recovery and billing, etc.) reported on an hourly basis have been obtained from each DISCO and aggregated on a monthly basis. National-level power grid data (megawatts generated, maximum allocations notified, actual power dispatched, etc.) have been obtained from the national grid operator. Details of the types of data utilized are given in **Section 2.2** below. The result of these pre- and post-project comparisons have enabled a quantification of load shedding patterns and the overall power demand and supply situation on a DISCO and country basis.

Evaluated direct impacts of the LDI project enable a further evaluation of the indirect and longer term benefits accruing to different sectors of the national economy, future prospects for the power sector itself, social impacts in terms of improved living and work conditions, and potential future benefits in the form of facilitating continued power sector reforms, improved business conditions, and better grid planning and investment decision-making.

2.1.2. INDIRECT LDI IMPACTS

The indirect economic and other benefits of the direct impact of the LDI project on load shedding and power delivery to end consumers have been estimated using previous detailed studies on the impact of power outages carried out in Pakistan and elsewhere. Impact factors have been derived and updated wherever possible before being applied to the direct impacts of LDI quantified separately, as described above.

A description of how different impact factors for each sector or group of affected beneficiaries has been derived from previous studies and corrected for current conditions, along with any

assumptions or approximations made, is provided along with the calculations made for each. Where it was not possible to obtain more current estimates due to information constraints, past factors have been used to provide a reasonable range of likely impacts. Other impacts which cannot be easily quantified under the scope of the present study but may have equally important future implications have also been identified and discussed qualitatively.

The direct and indirect impact of the LDI project can thus be evaluated separately (see **Section 3** and **Section 4**, respectively), based on which additional future potential benefits can be identified and recommendations made, as described in **Section 5** and **6,** respectively.

2.2. INFORMATION SOURCES

Details pertaining to the LDI project, including description of the scope, implementation, configuration, deployment schedule, and operational aspects, were provided by the PDP office. Further verification and clarifications were sought through direct communication and meetings with relevant project staff including project consultants. PDP also assisted in the provision of LDI meter installation project progress reports and cost breakdowns, and research papers on the impact of power outages.

Data on the national power grid, such as operational data on power generation, dispatch, distribution, load shedding schedules, billing, etc., was obtained directly from each DISCO and the NPCC. This was used to analyze the level of scheduled and unscheduled load shedding during pre- and post-LDI project periods (i.e., July to February for 2012-13 and 2013-14, respectively). DISCOs provided hourly and daily summary logs of load demand and supply, scheduled and unscheduled load shedding hours, and aggregated monthly billing data. From each DISCO (except for QESCO, PESCO and TESCO), load shedding implementation status (on hourly/daily basis), load management plans for the specified period, organizational charts and staffing details were also obtained. The NPCC contributed information on hourly grid-connected power generation, and scheduled load shedding allocations (DISCO-specific power ceiling allocations and energy flows).

Visits were undertaken by the consultants to various relevant offices and field locations to obtain firsthand information on the operation, experience and use of the LDI system and the data generated. This included extensive interaction with the operational staff at various power control centers, as well as meetings with senior and middle management personnel. PDC centers at IESCO, LESCO and PESCO as well as the NPCC control center were visited, some on multiple occasions. A joint meeting with representatives from all DISCOs was also conducted at the PDP office in Islamabad to learn more about their views and future plans and requirements with respect to the LDI project and general utility operations. A separate day-long visit to the K-Electric headquarters in Karachi was undertaken to assess the load management, smart

metering, and other advanced distribution plans being implemented by the privatized, vertically integrated power utility in order to learn about possible lessons that the LDI project could help implement at the state-owned DISCOs to help improve their performance and financial viability. A visit was also undertaken to the PITC control center at Water and Power Development Authority (WAPDA) House, Lahore, to learn about the LDI NOC set up there. A visit was conducted to MTI Industries, Lahore, to meet with the staff involved in the preparation of the LDI MDM software (Galaxy) developed by the firm and to learn about the LDI hardware configuration and operational features.

Additional information on the power sector was obtained from Hagler Bailly Pakistan (Pvt.) Ltd. (HBP) in-house resources on Pakistan's power sector, including databases on power supply and demand, and previously conducted studies on the economic evaluation of electricity supply to various sectors. External sources (publications, reports, web resources, etc.) were consulted for international best practices in utility operations and assessments on impacts of power outages on economic sectors as well as social indicators.

Due to the short timeframe for the study, additional visits and informal surveys of power consumers' perceptions of the LDI project could not be undertaken by the time the draft report was prepared for submission to PDP. This included interviews with industrial and trade organizations, and spot surveys of commercial businesses. In any case, such surveys were not intended to be statistically rigorous (due to time and resource constraints), rather provide anecdotal feedback on general perceptions on the reliability of the power supply and the load shedding situation during the pre- and post-LDI periods. It was not expected that the average consumer would have first-hand knowledge of the LDI project itself, let alone be able to discern its specific impact on load shedding, if any. Therefore, these interviews were not prioritized as much as the collection of hard utility operational data and records, which consumed the predominant proportion of the available study time to obtain, verify, compile, process and analyze.

However, the consultants faced critical information gaps in some key areas that were considered essential for identifying and evaluating the effects of LDI on overall national and utility-level power system performance metrics. For example, the NPCC provided hourly NTDC data for generation and load shedding (scheduled and unscheduled) for each DISCO for the periods of November 2012-February 2013 and November 2013-February 2014 only. Data for the periods of July-October 2012 and July-October 2013 was obtained from PDP in the form of average daily generation and total and forced load shedding for the aggregate NTDC system, with no division of load shedding at the DISCO level, making it difficult to assess the complete pre- and post-LDI periods of July-February for 2012-13 and 2013-14 on the same footing. Due to different data logging protocols and intermediate system losses involved, it was also not possible to accurately match the daily load data provided by each DISCO with the consolidated national reports obtained from the NPCC, and eventually the latter was relied upon for the impact analysis.

Details of primary and secondary data sources utilized for this study are provided in the **References** section at the end of this document.

3. DIRECT IMPACTS

National level power demand supply data provided by the NTDC was analyzed to assess the direct impacts, of the LDI project on system-wide load shedding. As described in **Section 2.2**, comparisons were made based on pre- and post-LDI project periods (i.e., July to February for 2012-13 and 2013-14 respectively).

3.1. IMPACT ON POWER SUPPLY QUANTITY

3.1.1. GENERATION DISPATCH

LDI is primarily designed to track and control the load imposed on the power system by DISCOs and manage load shedding to balance the system demand and supply from available generating capacity at any instant. Therefore, the LDI project will not have a direct impact on the total power generation capacity available at any time in the country (which is a function of available grid-connected generating units at the time which, in turn, are subject to seasonal variations in hydroelectric generation, planned and forced plant outages (e.g., for maintenance), and fuel stocks and gas supplies to thermal power plants). In addition, faults and constraints in the transmission system may prevent certain generation units from dispatch at a particular time. However, through more precise monitoring of system loads, grid balancing requirements, and the ability to better match power dispatch with actual load demand at the feeder, DISCO network, and national grid level, the LDI facility could conceivably help reduce the requirement for holding back a part of the generating capacity as the operating reserve required to meet any unforeseen supply shortages in the grid at short notice and for maintaining grid frequency within allowable limits.

3.1.2. OPERATING RESERVES

Electricity grids require the setting aside of a small percentage of available generation or power import capacity as “operating reserves“ to help maintain supply reliability and frequency control and maintain grid balance. The operating reserve is the generating capacity available to the system operator within a short interval of time to meet unforeseen or abrupt changes in loads or power delivery (e.g., in case a generator goes down or a transmission link trips). Generally, power systems are designed to maintain, under normal conditions, the operating reserve of at least the capacity of the largest generator plus a fraction of the peak load to be able to cater to

such eventualities. The operating reserve is made up of the "spinning reserve" as well as the "non-spinning reserve."[14]

The spinning reserve is the unused generating capacity that is available by increasing the power output of "hot" generators that are already in service and synchronized with the power system. For most generators, this increase in power output is achieved by increasing the torque applied to the turbine motor by increasing fuel input to plants. Spinning reserve is normally equal to the capacity of the largest generator in service at any time.

The non-spinning reserve, or supplemental reserve, is the extra generating capacity that is not currently connected to the system but can be brought online after a short delay (e.g., within 10 minutes). The supplemental reserve is normally maintained through power available from fast-start generators.

A potential benefit of LDI in terms of enhancing power availability for dispatch could be through a reduction of the operating reserve requirements on account of more precise load dispatch and demand monitoring that would enable operators to more accurately define spinning margins instead of the conservative estimates previously relied on in the absence of LDI-generated real-time grid data. Better load management, however, would not affect the supplemental reserve requirements.

However, in Pakistan, the national grid has reportedly been operating in recent years with zero spinning reserve margins[15]. This is because the NTDC system has been facing acute power shortages for the past five years that total as much as 5,000 to 6,000 MW, or almost 30% of the power demand, translating into daily load shedding durations in excess of seven to eight hours. Due to acute political and social pressures, the NTDC has been compelled to dispatch virtually the entire available generation capacity to minimize load shedding in the country. All non-hydro generators connected to the grid are therefore operated at full throttle whenever available (i.e., apart from during plant maintenance downtimes, low-water season, or due to transmission constraints), leaving little or no capacity for maintaining a spinning margin. In such a situation, the quality and security of the system is inevitably compromised, and results in chronic fluctuations in power frequency and voltage below the NEPRA-prescribed network standards (see **Section 3.2**).

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[14] There can also be "frequency-response reserve" and "replacement reserve," but for the present discussion they can be assumed to be included in the overall "operating reserve."

[15] Verified by Advisor, NPCC during the Meeting on April 21, 2014.

The NTDC ostensibly maintains supplemental reserves during the low-water winter months when hydropower generation becomes subject to limited water release indents issued by the government and the NTDC dispatches the available hydroelectric energy during peak loads only to gain higher capacity contributions from these comparatively inexpensive units for relatively short durations. The NPCC receives water release authorization from the Indus River System Authority for a five-day cycle in advance, which it has no authority to violate. The NPCC converts that into average daily releases and, depending on available reservoir head, computes the corresponding daily power generation capacity and energy generation from large hydropower plants that can be used during peak demand hours. Similarly, limited amounts of water are stored in small run-of-the-river hydropower plants during the off-peak hours of the day and released during peak hours to generate the needed electricity. These units are summoned for dispatch during off-peak hours at short notice only at critical instances (for very limited periods to remain within the water release allowance, or with specific prior government authorization on special occasions, e.g., during Ramadan), but not as general supplemental reserve service at the discretion of the grid controllers. During the high-water summer months (mid-June to September), hydropower units operate around-the-clock at full loads to make maximum use of water releases from reservoirs, again leaving no hydropower capacity to serve as reserve. The NTDC has been operating large hydro units in Pakistan in this manner as standard practice since the introduction of hydropower to the system, rather than when generation shortages started becoming a constant and not a peak load feature of the national grid. Since spinning reserve is a primary means of maintaining grid frequency (an indicator of instantaneous grid supply-demand balance), poor frequency control and significant forced load shedding prevalent in the pre-LDI period would also corroborate the absence of such stabilizing reserves or, at a minimum, its inadequacy to serve its intended purpose in a severely supply-constrained national grid.

Despite all evidence to the contrary, if any operating reserve is indeed actually maintained by the NTDC, information on this is not available at this time and therefore a final determination cannot be made in this report as to the possible impact of the LDI in terms of releasing some reserve power supply margin to help meet demand and reduce load shedding hours. It may be useful to add that in the future, if sufficient generation capacity is developed in Pakistan that can adequately meet demand and routine load shedding is finally eliminated, the LDI facility will help optimize the operational reserve requirements better, resulting in a more productive use of generation assets.

3.2. IMPACT ON POWER QUALITY

The utility line frequency (or mains frequency) is the sole indicator of the overall health of the power grid system; other power quality parameters, such as RMS and peak voltages, harmonics, transient currents, etc., are largely affected by local or regional conditions on the distribution networks (such as transformer and feeder overloading, power factor, weather impacts, etc.).

Deviations in power quality from prescribed standards set by the regulator can affect all kinds of end-use equipment powered by electricity, from elements of the power infrastructure itself (e.g., transformers) to industrial machinery as well as commercial, municipal and domestic devices. This can result in disruptions in the power supply itself (due to tripping, blown fuses, etc.) to malfunctioning or overheating of equipment (lighting, motors, transformers, communication links, etc.), complete shutdown of sensitive devices (particularly synchronous motors, sophisticated electronic devices, including certain medical instruments), and even permanent damage (electronics, process control systems, etc.). The consequences of poor power quality can therefore range from consumer inconvenience to a reduction in economic and industrial activity and output, as well as the associated costs of equipment damage, repair and replacement.

While the net economic impact of poor power quality would depend on the nature, extent, and persistence of such issues in the power supply as well as load and consumer characteristics, it is obvious that this would nonetheless be adverse and costly at the national level. **Exhibit 3.1** shows illustrative Europe-wide estimates (based on surveys conducted over two years in eight countries) for the direct financial impact of power quality incidents on downstream sectors, which does not include the knock-on economic losses that could also result. While similar assessments for Pakistan have not been undertaken, the magnitude of potential losses due to quality issues, as seen in the table, can be presumed to be significant.

For the purpose of grid stability and to minimize downstream damage, NEPRA has prescribed frequency standards in the Grid Code[16] for the NTDC to adhere to in meeting the target national grid frequency of 50 Hz. This allows for nominal deviations (called the "Frequency Sensitive Mode") from 49.8 Hz to 50.2 Hz (due to unavoidable reaction times in meeting transient load-supply imbalances), operation for limited duration ("Tolerance Frequency Band") between 49.5 Hz and 50.5 Hz, and absolute minimum and maximum limits ("Contingency Frequency Band") of 49.4 Hz to 50.5 Hz. NTDC is not allowed to let the system frequency drift from these regulatory limits for more than 5 to 10 minutes in the first two cases, while in the case of contingency, the frequency must be restored to the "Contingency Frequency Band" within 60 seconds and to the Tolerance and Frequency Sensitive ranges within 5 to 30 minutes, respectively, thereafter. Failure to maintain the frequency at a minimum of 49.4 Hz, in the absence of sufficient operating reserves, shall compel the grid operator to initiate forced load shedding on the grid. In addition, large generating units have automatic generator control (AGC) governors and frequency relays installed that shut down the unit if the instantaneous line frequency falls below 48.5 Hz or exceeds 51.0 Hz in order to protect the generator and to preempt system cascade failure.

[16] Under Operation Code 4.8.

Exhibit 3.1: European Estimates of Financial Losses Due to Power Quality Incidents[17]

Sector	Financial Loss per Incident
Semiconductor production	€3,800,000
Financial trade	€6,000,000/hour
Computer centers	€750,000
Telecommunications	€30,000/minute
Steel industry	€350,000
Glass industry	€250,000
Offshore platforms	€250,000-750,000/day
Dredging/land reclamation	€50,000-250,000/day

* An 'incident' is defined as the stoppage of susceptible equipment as a result of poor power quality at the mains supply.

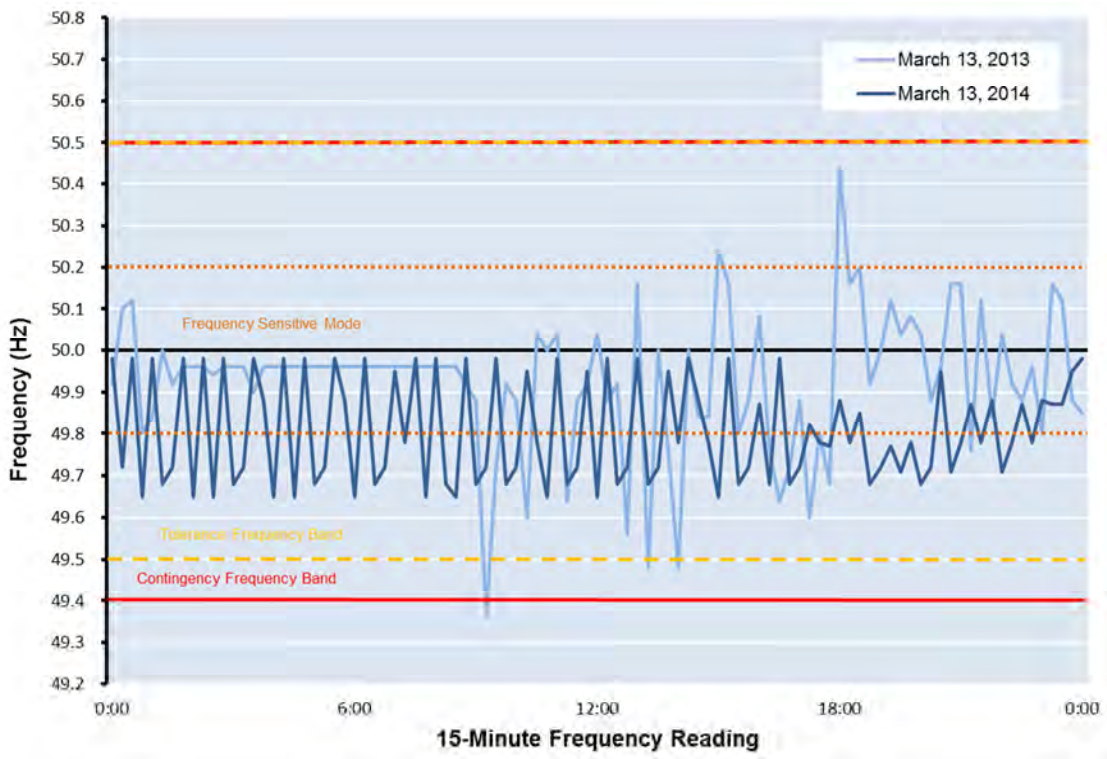
Historical data on instantaneous frequency values is difficult to obtain, as prior to mid-2013, this was recorded by NPCC on analog chart plots, used only as archival reference. As was stated in **Section 0**, prior to LDI implementation, grid operators used only simple digital frequency meters (**Exhibit 1.1**) to balance and manage the grid. However, by late 2012, the NTDC commissioned a system-wide SCADA system on the network, which provides frequency readings every second. This data stream is now also displayed on the LDI operator screens, and recorded in the digital database along with other monitored parameters. However, at the time of preparation of this report, only limited frequency data for the pre- and post-LDI periods had been made available by the NPCC, enabling only a broad, qualitative comparison of grid power quality in the two cases.

One such set of random frequency data is shown in **Exhibit 3.2**, which shows comparative 24-hour frequency curves (with a 15-minute instantaneous recording interval) for the same day (March 13) in 2013 (pre-LDI) and 2014 (post-LDI), respectively. Both dates fell on weekdays (Wednesday and Thursday, respectively), and so can be taken to represent similar seasonal and daily load and ambient conditions. Although not statistically representative, the plot shows some interesting features. It can be seen that in the pre-LDI sample, the amplitude of frequency variations is generally higher (with a standard deviation (SD) of 0.168) than in the post-LDI sample (SD of 0.125), with a ΔSD of 25.74% between the two cases. In the pre-LDI case, the frequency exceeded the Frequency Sensitive Mode range of 50 Hz on both sides on several occasions, while it also fell below the Tolerance Frequency Band several times and the

[17] Targoz [2007].

Contingency Frequency Band at least once. This is symptomatic of not only poor grid control (due to the lack of sufficient information with the controllers on which to take corrective measures), but also of the possible absence of available spinning reserves. The fact that in the pre-LDI period, there are several instances of over-frequency excursions in a severely supply-constrained situation, only highlights that power dispatch was not being undertaken optimally, and controllers were forced to overcompensate at times as a means of coping with indeterminate load patterns, with system frequency being their only indicative guide.

Exhibit 3.2: Grid Frequency Recorded on March 13, 2013 and March 13, 2014



In the post-LDI frequency sample shown in Exhibit 3.2, there appears to be a marked improvement in terms of a well-defined band of frequency deviations which is both more stable and narrower. In this case, the Tolerance and Contingency Frequency Bands are never violated, although the lower bound of the Frequency Sensitive Mode is routinely exceeded (as was the case in the pre-LDI period[18]).

[18] It is not clear why the recorded frequency for the pre-LDI date shows zero variation from 03:00 to 08:30 hours, but this would appear to be a recording error.

It is not surprising that the mean frequency during the 24 hour-period remains below 50 Hz in both cases (49.93 Hz and 48.81 Hz, respectively, for the pre- and post-LDI sample shown), indicating a generation-constrained operating scenario with insufficient operating reserves. In such a situation, the grid operator routinely allows the frequency to drop below 50 Hz, in order to be able to serve a larger load with the available power supply. In other words, in practical terms, the system seems to hover around the lower bound of the Frequency Sensitive Mode (49.8 Hz), instead of the system target value (50 Hz). In such a case, the repeated violation of the minimum Frequency Sensitive Mode allowance is inevitable. This seems to be the case in both the pre- and post-LDI cases, again indicating that the overall power supply constraint remains unchanged; however, in the post-LDI period, the rest of the frequency deviation bands seem to be better respected and the overall variation bandwidth is markedly reduced.

It should be noted here that it is a fallacy to assume that by supplying power at a lower frequency, the grid operator is able to service a larger load in terms of power delivered (i.e., megawatts). In reality this is not the case, as the power delivered cannot exceed the power produced by the generators. However, by lowering the frequency, the operator is able to supply electricity to a larger number of consumers, albeit of a poorer quality (i.e., lower RMS current). Since load shedding is politically sensitive, the operator prefers to keep the maximum number of customers connected at any time, instead of maintaining strict frequency compliance. In this regard, it is noteworthy to point out that in Exhibit 3.2**,** while in the pre-LDI data set the frequency comes close to or crosses the "forced load shedding threshold" of 49.4 Hz several times, in the post-LDI plot the frequency is maintained well above this value at all times, corroborating the assessment of the impact on forced load shedding presented in **Section 3.3.2**.

The observations made above are indicative of a positive impact of LDI on system frequency, and therefore, on the maintenance of a system-wide power quality. Not only would this help reduce electricity supply disruptions and damage to the power infrastructure (particularly transformers, where frequency-induced damage is cumulative) and improve the longevity of system components, but it would also result in a more optimal dispatch of available power, and reduce the inconvenience and material losses suffered by consumers—and the economy—as a result of power quality variability. Additional data on grid frequency characteristics, as and when they become available, could help provide a more definitive assessment of the lasting impact of LDI on grid power quality.

3.3. IMPACT ON POWER LOAD MANAGEMENT

The LDI project does have a direct impact on grid load management where it helps in forecasting as well as measuring shortages and allocates them to different DISCOs in order to maintain the load balance with generation in real-time.

3.3.1. PLANNED AND UNPLANNED LOAD SHEDDING

Load shedding is recorded by the utilities under different categories: scheduled and unscheduled, mainly owing to expected and unforeseen generation shortages, respectively, and forced load shedding carried out due to T&D constraints, faults and other reasons.

Based on the projected total generation of power in the country over the next 24 hours, the NPCC allocates proportional[19] power supply allocations, or "load quotas", to all DISCOs on a daily day-ahead basis—in effect defining a ceiling beyond which they cannot draw power from the NTDC over the next 24 hours. The DISCOs convert their projected shortfalls into a schedule of hourly "planned" load shedding for various customer categories in accordance with their respective load management policies, and communicate the predetermined feeder-level planned outages, corresponding to the overall hourly shortages and the relevant grid operators at various substations. Based on the DISCOs' program of feeder outages in each hour, aggregate system wide "scheduled" hourly load shedding profiles are then prepared by each DISCO and returned to the NPCC for a compliance check with their respectively assigned power allocations.

The scheduled or planned load shedding program is designed to minimize its impact on consumers, reduce damage and losses to the economy, and ensure equitable sharing of the resulting inconvenience across geographical and consumer categories, to the extent possible. However, DISCOs regularly resort to differentiated load shedding schedules, with large urban and industrial consumers prioritized for power supply at the cost of poor or rural communities,[20] who are subjected to extended outages of up to 12 hours a day. On urban and industrial feeders, scheduled load shedding is conducted in cycles of whole hours, wherein only one hour of continuous load shedding is carried out in each cycle for any feeder, strictly in sync with the clock (i.e., at zero past the hour).[21] The purpose of such a planned load shedding program is to enable consumers to be able to predict and adjust to the outages and to minimize the resulting losses and damages. Feeder-level planned load shedding schedules are generally changed every three months, to minimize unpredictability and inconvenience while allowing rotation of outage times amongst all consumers. However, in instances where DISCOs get temporary relief or additional allocations from the NPCC, they reduce or eliminate load shedding hours accordingly.

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[19] These allocations are based on the proportionate load demand for each DISCO obtaining in 2003, the latest year in which there was zero load shedding in the country. These ratios have not been updated since, although load patterns would have changed in the subsequent decade, on account of a lack of a verifiable basis.

[20] Particularly in poorly performing or geographically stretched DISCOs, such as PESCO, QESCO, and HESCO, where poor households form the bulk of the customer base and access, and therefore bill recovery, is low due to large distances involved or security concerns.

[21] Some feeders serving "essential" loads are exempted from load shedding due to security, political, or social imperatives.

Apart from rural and poor households bearing the brunt of power disruptions, there are also other exceptions to this arrangement. For instance, QESCO and PESCO face constant constraints in their transformation and distribution functions due to capacity, access, and low recovery rates in certain areas, forcing them to carry out significant amounts of unavoidable load shedding in those regions regardless of their NPCC allocations. Consequently, both of these DISCOs generally do not exceed their NPCC-allocated quotas but, in fact, undrawn their allotted shares. Over the past two years, QESCO and PESCO have been exempted from general "scheduled" load shedding directives from NPCC-allocated quotas but in fact drew less than their allotted shares, and over the past year or two have been exempted from general "scheduled" load shedding directives from NPCC issued to the DISCOs (for a detailed discussion of DISCO allocations and loads drawn, see **Section 4.3.1**).

At times when the NPCC is required to shed load due to transmission line faults, grid station outages, or NTDC system overloads, the relevant DISCOs are directed to curtail their affected feeders during the stress period. In cases where the load exceeds available generation due to a sudden rise in demand or loss of generation capacity (and in the absence of grid operational reserves, as discussed in **Section 3.1.2**), the NPCC directs DISCOs to carry out emergency load shedding, called "unplanned" or "forced" load shedding on short notice to save the power system from tripping. In the pre-LDI era, the NPCC did not have an exact knowledge of specific DISCO loads and used to frequently resort to forced load shedding through the NTDC system in order to maintain system balances, plunging large areas into darkness with no prior warning.

For the purposes of this study, "planned" or "scheduled" load shedding refers to outages which are predetermined by the DISCOs, and may be communicated to consumers in advance, and carried out in accordance with a strictly observed time schedule. "Unplanned", "unscheduled" or "forced" load shedding applies to all other outages resulting from unexpected generation shortfalls, transmission or distribution system constraints or faults, emergency maintenance shutdowns, etc., which are not communicated to consumers in advance. This distinction is important not only for assessing overall grid performance and service delivery parameters (with "planned" outages being unavoidable and therefore not attributable to operational deficiencies), but also because the relative impact, and therefore costs and benefits, of planned versus unplanned power outages are different, as described in **Section 4.1.2**.

3.3.2. IMPACT ON LOAD SHEDDING

Exhibit 3.3 presents the average monthly power balance on the NTDC system for both the pre-LDI project period (July 2012-February 2013) and post-LDI project period (July 2013-February 2014), computed using a combination of NTDC and PDP data sources. It can be seen that the

average monthly generation dispatched in the post-LDI period increased by about 643 MW, which can be attributed to various factors, including the addition of nearly 226 MW of new hydroelectric and 106 MW of new wind capacity, as well as increased availability of other plants in the system (the contribution from the latter is expected to be higher than the remaining 311 MW differential, as actual new generation dispatch would be less than the full rated capacities of the new plants).

Exhibit 3.4 presents the detail of new generation capacity added to the NTDC system during the post-LDI period of July 2013 to February 2014. The average availability of these plants would vary each month, subject to the availability of water and wind resources, and therefore they would operate below their full rated capacities (annual plant factors for wind farms are typically <30%). Thus, the bulk of additional capacity (>311 MW, the differential between additional supply and new capacity additions) can be assumed to result from the higher availability of existing plants due to, for instance, the USAID-funded rehabilitation of some GENCO plants, increased supply of fuel to thermal units, and enhanced payments to independent power producers (IPPs) made by the government as a partial measure to ease the power sector circular debt.

As expected, the overall seasonal profile of total generation in the country is otherwise similar for both pre- and post-LDI periods.

Exhibit 3.3: Pre- and Post-LDI Project Power Balances on NTDC Grid

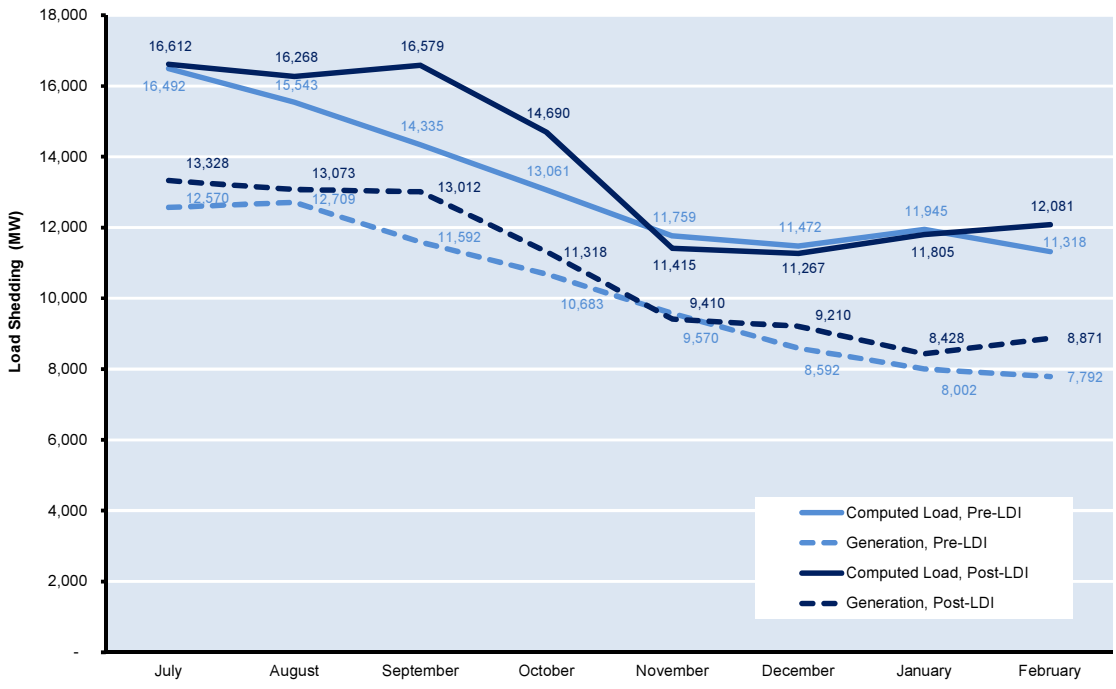


Exhibit 3.4: New Generation Capacity Added to Grid during Post-LDI Period

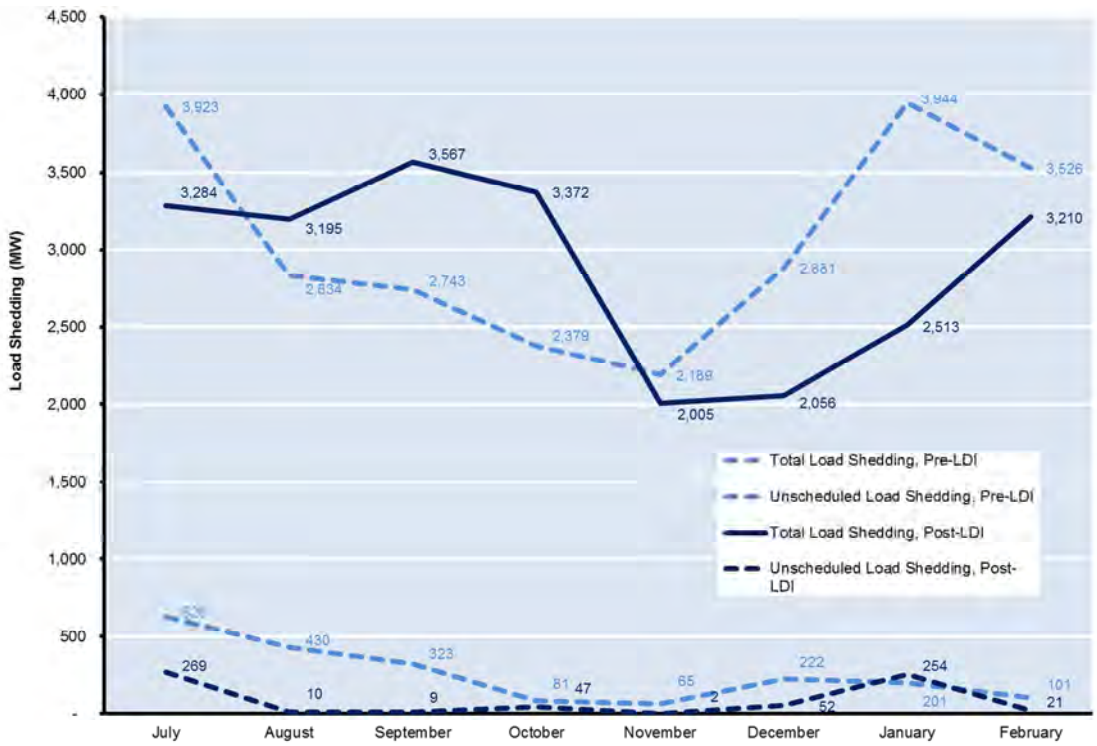
Plant	Rated Capacity (MW)
Jinnah Hydropower	96
Dubair Khwar Hydropower	130
FFCEL Wind	50
ZEPL Wind	56
Total New Generation	**332**

The overall system load has been calculated by adding total "computed" load shedding to the average generation for each month. The computed load shedding is the sum of planned load shedding, as described in the preceding section, as well as any forced outages resulting from unforeseen supply shortages, system faults, or other factors recorded during the period. It

should be mentioned that the “computed” total megawatts logged as “load shed” under the categories above are not necessarily the actual amounts shed (in terms of unmet power demand) due to the following factors: firstly, the computation is based on the aggregation of the load ‘last drawn’ from feeders immediately before that feeder was disconnected at the onset of load shedding, and is not based on the actual demand profile over the subsequent load shedding period, which may vary significantly from its instantaneous initial value. Secondly, under a constantly supply-constrained situation, real peak loads on the system cannot be measured on account of unserved demand that goes unrecorded. And finally, this estimated load shedding also does not factor in the latent demand of the unconnected population or of those willing to pay for reliable, uninterrupted supplies, which would increase the overall power demand on the system. Therefore, the computed load shown in

Exhibit 3.3 should not be construed as the total electricity demand on the system, *per se*, but only a rough approximation of the actual average daily total load shedding as recorded by the utilities for their own reporting purposes.

Exhibit 3.5: Pre- and Post-LDI Project Total and Unscheduled Load Shedding on NTDC Grid



Note: Post-LDI data for July 2013 include nine days preceding LDI commissioning.

Therefore, the computed load shown in

Exhibit 3.3 should not be construed as the total electricity demand on the system, *per se*, but only a rough approximation of the actual average daily total load shedding as recorded by the utilities for their own reporting purposes.

Exhibit 3.5 presents a comparison of total and unscheduled load shedding for all DISCOs for the same pre-LDI and post-LDI periods. It can be seen from this data that total load shedding increased between August and October in the post-LDI period compared to the year before, while showing a reduction during the November to February period. However, the proportion of forced load shedding in the total load shed consistently receded over the post-LDI period

compared to the pre-LDI period on a month-to-month basis, which could be attributed to availability of LDI data that provides an accurate, real-time picture of the load that each DISCO is drawing from the system at any given time, making it possible to predict supply-demand shortages and plan the load shedding in advance. In the event where a DISCO persists with drawing power beyond its allocated hourly quota from the grid, the NPCC issues specific directives to the errant DISCO to bring its load within the allocations through forced shedding. The onus for unplanned or forced load shedding has therefore clearly shifted from the NTDC to DISCOs in the post-LDI era, as the latter now have to manage and minimize forced load shedding within their service regions based on their LDI-provided load profiles and internal policies and priorities.

A consistent decline in instances and amounts of unscheduled load shedding in the post-LDI period has been observed, except for the month of January 2014 (see below). For instance, **Exhibit 3.6** presents the average daily hours of unscheduled load shedding for all nine DISCOs,[22] based on the frequency of unscheduled load shedding directives issued by the NPCC to the DISCOs, which are lower by nearly 85% for the post-LDI period.[23]

Exhibit 3.7 presents the shares of scheduled and unscheduled outages in total monthly load shedding during the pre-LDI period, while **Exhibit 3.8** presents the same data for the post-LDI months. Despite the fact that the LDI project was commissioned in July 2013 and was going through its initial testing and troubleshooting in subsequent months, it is evident from these exhibits that there is a coincident immediate reduction in forced load shedding across the country, beginning in July 2013.[24] Forced load shedding in the post-LDI period appears to have been consistently reduced when compared with the same period over the previous year, except for the month of January 2014 when forced load shedding increased in the post-LDI period compared to the same month a year ago. The reason for this conspicuous increase in unplanned load

22 Calculated by adding the actual daily hours of forced load shedding at each DISCO, computing the monthly daily averages, and then averaging over all DISCOs.

23 Excluding January 2014, for reasons explained subsequently. Including January, however, the frequency of unscheduled load shedding instances is still reduced by 50% in the post-LDI period.

24 In fact, the reduction is evident in the daily load shedding pattern starting on July 9, 2013, the day the LDI project become operational at nine DISCOs. The coincident and sustained reduction thereafter in unscheduled load shedding indicates a very strong correlation with the LDI project, especially given the absence of other probable causes.

shedding during this one month can perhaps be attributed to an unusually significant loss of generation capacity in that month caused by diversion of natural gas supplies to the domestic sector for heating purposes during a severe cold spell, leading to a shortage of gas for thermal power generation. Records corroborate that the 395 MW Rousch Power IPP had to be shut down due to deficient gas supplies, while there was an unforeseen extended shutdown of the 235 MW Liberty Power.[25] In addition, possible better compliance with the mandated grid frequency of 50 Hz during the post-LDI period (see **Section 3.2**) would also reduce operational margins before resorting to forced outages becomes necessary, therefore increasing such unscheduled load shedding instances in a severely supply-constrained scenario. Standing government directives to not subject the industrial sector to unnecessary power supply disruptions, coupled with reduced available generation capacity, would also have resulted in DISCOs having to carry out additional (unplanned) load shedding for other customer categories in order to maintain system balance. These factors cumulatively could be the cause of the apparently anomalous data for January 2014 seen in
Exhibit 3.3, **Exhibit 3.8,** and **Exhibit 3.10**. January 2014 can therefore be considered an outlier in the data set, and has been excluded from further analysis.

With January 2014 excluded, **Exhibit 3.9** and **Exhibit 3.10** clearly depict a significant drop in the proportion of unscheduled load shedding in total monthly load shedding in the post-LDI period. Given the evident correlation between the commissioning of LDI operations and the sharp change in the forced load shedding pattern, it can be surmised that overall unscheduled load shedding on the NTDC grid dropped to negligible amounts (<3%) as a consequence of the LDI project (as there are no other contributing factors to account for this simultaneous change). Based on seven-month averages of total and forced load shedding, however, no change was found in the amount of total load shedding. This indicates, at a minimum, that any net additional generation capacity (e.g., through new plants or reduced spinning reserve margins) made available for dispatch during this period was subsumed by the natural growth in power demand over the year

Exhibit 3.6: Average Daily Hours of Unscheduled Load Shedding Across Nine DISCOs

[25] The plant was forced to shut down on November 15, 2013 due to turbine blade damage that required major repairs, and re-commissioned on March 28, 2014.

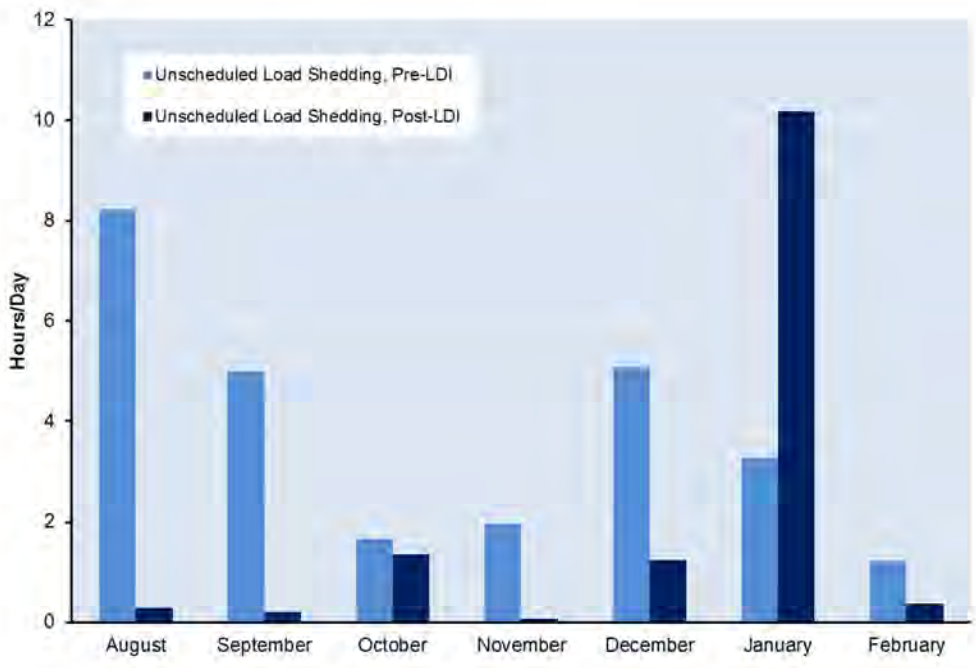


Exhibit 3.7: Pre-LDI Project Monthly Scheduled and Unscheduled Load Shedding on NTDC Grid

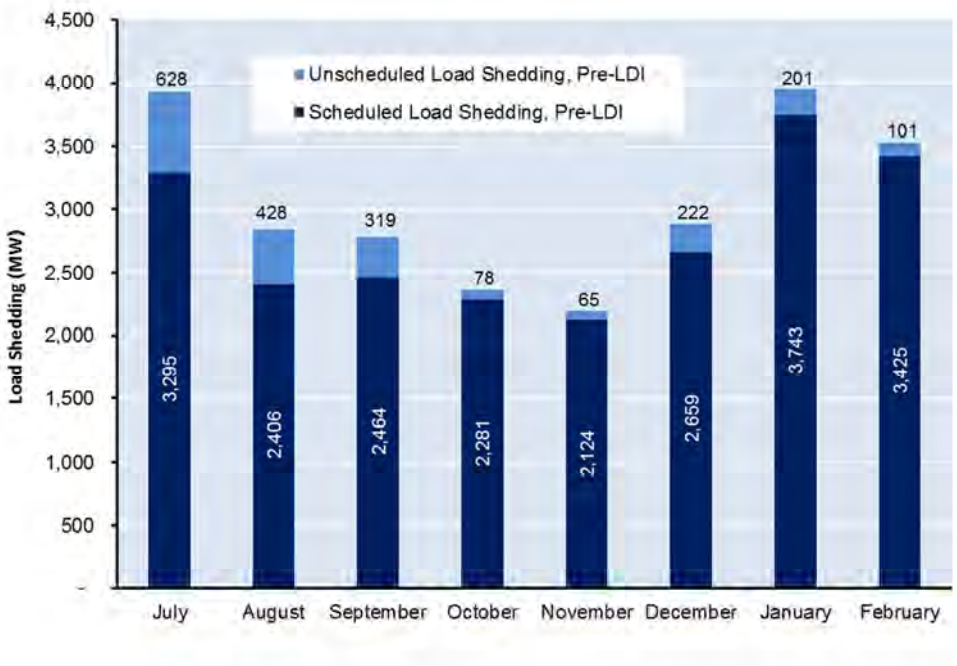


Exhibit 3.8: Post-LDI Project Monthly Scheduled and Unscheduled Load Shedding on NTDC Grid

Note: Post-LDI data for July 2013 include nine days preceding LDI commissioning.

Exhibit 3.9: Proportion of Pre-LDI Project Scheduled and Unscheduled Monthly Load Shedding

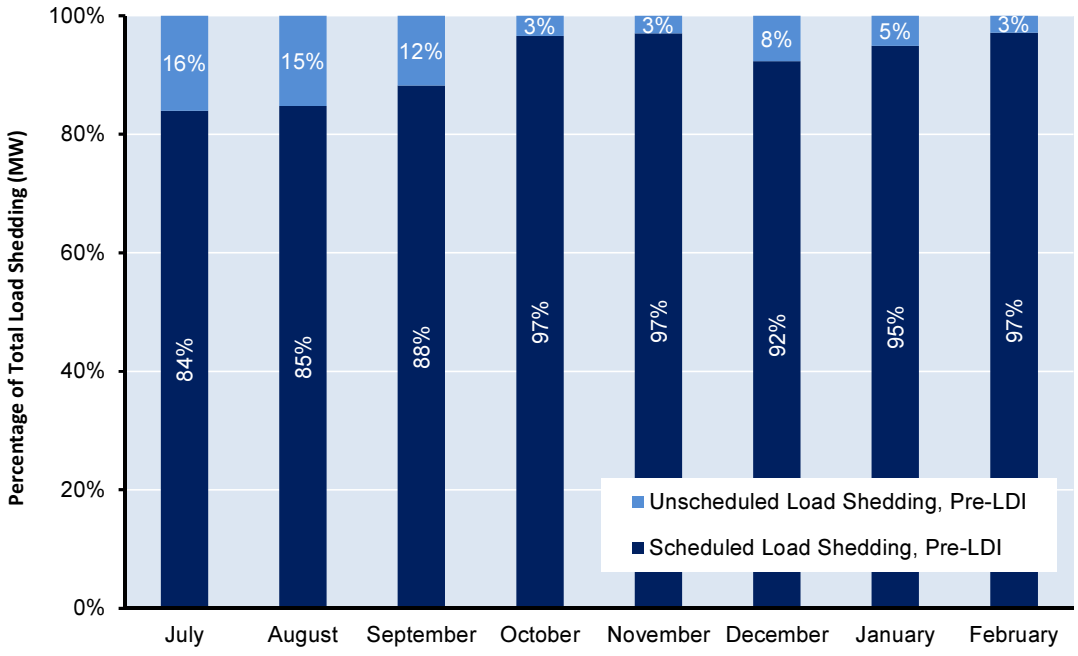
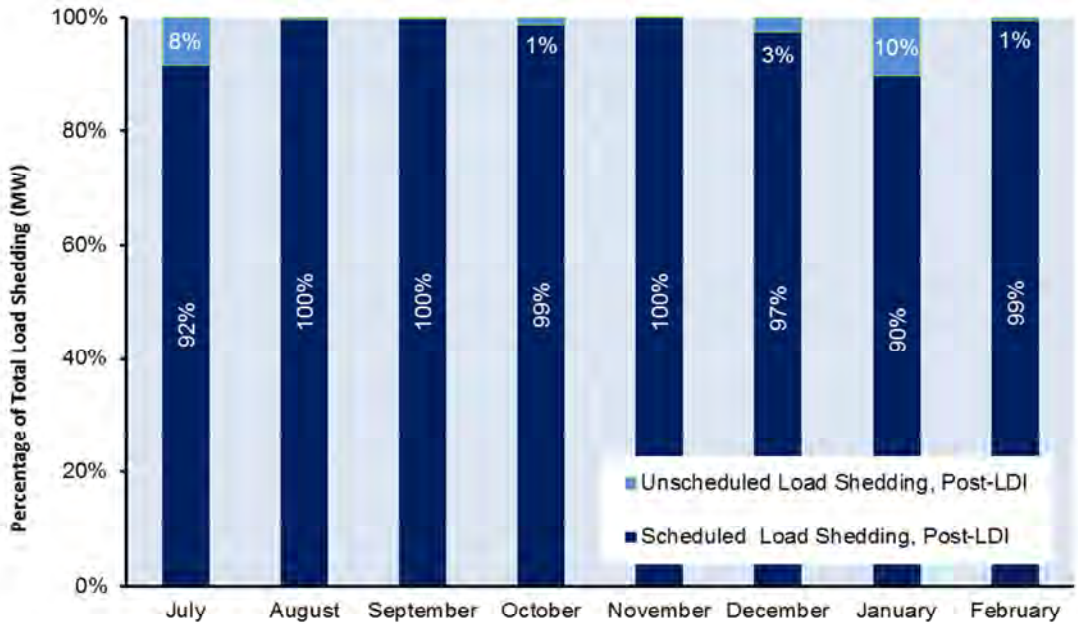


Exhibit 3.10: Proportion of Post-LDI Project Scheduled and Unscheduled Monthly Load Shedding



Note: Post-LDI data for July 2013 include nine days preceding LDI commissioning.

Nevertheless, a clear shift away from forced load shedding has been observed which is coincident with the operationalization of the LDI project, to the current situation where load

shedding is almost always implemented according to planned schedules, with forced load shedding dropping from an average of 9% of the total load shed earlier to only 2% now. This translates to a shift of about 200 MW, corresponding to 1,805[26] GWh in energy terms over a year, from unscheduled to scheduled load shedding.

The summary calculations of the LDI impacts on the scheduled and unscheduled load shedding are presented in **Appendix A** and **Appendix B**.

[26] The total annual energy moved from shift of 206 MW from unscheduled to scheduled load shedding = 206 MW x 8760/1000 (GWh)

4. INDIRECT IMPACTS AND BENEFITS

4.1. NATIONAL LEVEL IMPACTS

The impact of disruptions in the supply of reliable power to consumers at the national level include a) immediate and direct economic losses, such as the loss in industrial production, agricultural losses, and the monetary value of affected commerce, etc., b) longer term factors that affect future growth prospects, such as export competitiveness, investor confidence, and business outlook, and c) indirect costs, such as affected livelihoods and social services (health, education, transport, etc.) that also help define quality of life, human development, and poverty levels, in the longer run. While it is not possible to quantify or isolate the specific impact of persistent load shedding on the above, it is important to recognize that power outages can negatively impact the country's economic development through such multiple and broad factors, and to try and estimate the magnitude of some of these losses to the extent possible.

4.1.1. ANALYSIS OF OUTAGE COSTS

The immediate impact of power disruptions on various economic sectors has been researched by economists internationally, and found to be sensitive to various factors (economic development, energy intensity, composition of GDP, geographical and demographical context, etc.) that make it difficult to draw simple quantitative conclusions.

Exhibit 4.1 summarizes the results of relevant international and local analyses conducted over several decades on the impact of power outages on various economic sectors. The variance in the average cost per kilowatt-hour estimated in the international studies is symptomatic both of differences in the methodologies employed as well as in the nature and disparity between the underlying data sets, and can therefore only be used to provide an indicative range of values for each sector.

In the case of Pakistan, a number of studies have also been conducted that are more relevant, and although these are few in number, some are not very recent and others are based on simplified methodologies or focus on specific sectors only. A summary of their analysis results is shown in **Exhibit 4.2** and a brief description of the sector assessment of economic impact of power outages is provided below.

4.1.1.1. INDUSTRIAL SECTOR

Studies that focused specifically on the Pakistan economy also report the multiplier effect of power outages for the industrial sector, beyond the primary reduction on economic output and direct outage costs in terms of lost production (idle factor), spoilage, adjustments (equipment degradation, schedules, self-generation), that include the decline in the level of economic activity in other sectors, such as agriculture, wholesale and retail trade, transport and communications, banking and insurance, etc. These studies have been carried out based on actual national surveys of industrial units, disaggregated into type (e.g., textiles, chemicals, food, metals, machinery, etc.), process (continuous or batch), location (province), and accounting for relevant costs, outage hours, operational adjustments, etc., reported by each unit. The calculated losses for each category in the sample data have then been averaged and extrapolated to the national level (and corrected for any sample biases) using statistics on the total number of relevant industrial units in the country to arrive at, for instance, the percentage impact of outages on value added, value of production, and exports, as shown in **Exhibit 4.2**.

Exhibit 4.1: International Estimated Cost of Power Outages to Different Types of Consumers

Sector/Approach	Study	Average Outage Cost ($/kWh)
Residential Sector		
Standby generator cost	Sanghvi [1980: USA]	2.25
Value of leisure	Sheppard [1965: UK]; Lundberg [1970: UK]; Yaborf [1980: USA]; Munasinghe [1977: Brazil]; Turner [1977: New Zealand]	2.10
WTP survey	Lundberg [1970: Sweden]; Ontario Hydro [1977: Canada]; Finnish Power Producers Council [1978: Finland]; Yaborff [1980: USA]; Faucett [1979: USA]; Systems [1980: USA]	1.04
Estimated by survey	Balducci [2002: USA]	0.75
Consumer surplus loss	Sanghvi [1980: USA]	0.58
Industrial Sector		
Estimated by survey	Swedish Electric Council [1969: Sweden]; Modern Manufacturing [1969: USA]; Gannon/IEEE [1971: USA]; IEEE [1973: USA]; UNIPEDE [1970: Sweden]; Jackson & Salvage [1974: UK]; Ontario Hydro [1977: Canada]; Sanghvi [198: USA]; Balducci [2002: USA]	4.25
Value added lost	Lundberg [1970: UK]; Taiwan Power Co. [Taiwan: 1975] Yaborf [1980: USA]	3.46

Cost of wages lost	Sheppard [1965: UK]; Turner [1977: New Zealand]	2.21
Commercial Sector		
Estimated by survey	Lundberg [1970: Sweden]; Patton [1975: USA]; Congressional Research Service [1979: USA]; Ontario Hydro [1978: Canada]; Finnish Power Producers Council [1979: Finland]; Balducci [2002: USA]	6.65
Cost of wages lost	Sheppard [1965: UK]; Turner [1977: New Zealand]; Yaborf [1980: USA]	3.30
Agricultural Sector		
Estimated by survey	Balducci [2002: USA]	0.65

Exhibit 4.2: Estimated Cost of Power Outages to Different Types of Consumers in Pakistan

Sector/Approach	Source	Average Outage Cost ($/kWh)	Inflation Adjusted Average Outage Cost ($/kWh)	Total Annual Cost	Inflation Adjusted Total Annual Cost	Remarks
Industrial Sector						
Reduction in value added	Pasha [1989]	0.50	0.95	$331 million Rs 6.2 billion	$626.6 million	1.3% of GDP
Planned		0.36	0.68			5.7% of value added
Unplanned		0.63	1.19			8.8% of value added
Industrial outage costs to other sectors				$112.1 million (Rs 2.1 billion)	$212.2 million	Multiplier of 1.37 impact of industrial losses on other sectors, or 0.46% of GDP
Industrial sector losses	IPP [2009]			$1.92 billion (Rs 157 billion)	$2.1 billion	
Industrial outage costs to other sectors				$649.5 million (Rs 53 billion)	$710.5 million	
Large scale industry	Siddiqui [2011]	0.55	0.57	$2.7 billion (Rs 231 billion)	$2.8 billion	
Industrial sector losses				$2.5-9.5 billion (Rs 216-819 billion)	$2.6-9.9 billion	
Industry, overall	Pasha [2013]	0.54	0.54	$3.1 billion (Rs 314 billion)	$3.1 billion	1.5% of GDP

Sector/Approach	Source	Average Outage Cost ($/kWh)	Inflation Adjusted Average Outage Cost ($/kWh)	Total Annual Cost	Inflation Adjusted Total Annual Cost	Remarks
Small scale industry		0.52	0.52	$819.5 million (Rs 83.2 billion)	$892 million	
Reduction in annual exports	Pasha [1989]			$75 million (Rs 1.4 billion)	$142 million	4.2% of total exports
	IPP [2009]			$919.1 million (Rs 75 billion)	$1 billion	5.2% of total exports
	Pasha [2013]			$3.5 billion (Rs 355.3 billion)	$3.53 billion	14% of total exports
Commercial Sector						
Commercial services, overall	Pasha [2013]	0.69	0.70	$4.65 billion (Rs 472 billion)	$4.68 billion	2.4% of GDP, 4.5% of value added
Residential Sector						
Overall, residential	Pasha [2013]	0.23	0.23	$2.36 billion (Rs 240 billion)	$2.39 billion	
Urban domestic		0.24	0.24	$1.93 billion (Rs 196 billion)	$1.95 billion	
Rural domestic		0.18	0.18	$433.4 million (Rs 44 billion)	$436.9 million	

Sector/Approach	Source	Average Outage Cost ($/kWh)	Inflation Adjusted Average Outage Cost ($/kWh)	Total Annual Cost	Inflation Adjusted Total Annual Cost	Remarks
Agricultural Sector						
Crop, dairy and domestic losses	Pasha [2013]	0.30	0.30	$875.6 million	$882.6 million	2.3% of value added
Overall National Losses						
Total outage costs	Pasha [1989]			$443.1 million (Rs 8.3 billion)	$838.8 million	1.8% of GDP
	IPP [2009]			$2.4 billion (Rs 210 billion)	$2.5 billion	2% of GDP
	Pasha [2013]			$14.2 billion (Rs 1.4 trillion)	$14.3 billion	7% of GDP
Total direct costs	Pasha [2013]	0.38	0.38	$10.8 billion (Rs 1.1 trillion)	$10.9 billion	5% of GDP

4.1.1.2. COMMERCIAL SECTOR

The methodology for estimating the impact of power outages on the commercial sector adopted in these studies is similar to that followed for the industrial sector, i.e., based on a sample survey of broadly categorized, geographical representative establishments, with costs attributed to productive time lost (including load shedding duration, seasonality effects, etc.), idle factor (e.g., labor), lost sales (customers, spoilage), and adjustments (self-generation, timings, etc.), extrapolated to the national level using category-wise annual value added statistics (excluding defense and public administration).

4.1.1.3. RESIDENTIAL SECTOR

While it is not possible to assess the full impact of load shedding on domestic consumers, which includes many secondary and intangibles effects—such as on quality of life and comfort levels, educational and leisure opportunities, health, and other social factors, direct impacts—such as costs relating to monetization of utility losses (due to consumers' willingness to pay higher

electricity tariffs for uninterrupted service), adjustments (generators and uninterrupted power supply) and other factors (e.g., spoilage, foregone income, etc.).—have been estimated in the past based on random household sampling across provinces and income groups. The resulting outage costs per unit of electricity for each income group are multiplied by national household census data to arrive at the total impact of load shedding on the country's residential and domestic sector.

4.1.1.4. AGRICULTURAL SECTOR

The impact of power outages on the agricultural sector is assumed to be solely due to the value of crop losses attributable to disruption in irrigation water supply on account of reduction in total electric tube well operational hours. For this, national data (by province) on the share of crop output grown on irrigated lands, share of irrigation provided by tube wells, percentage of tube wells running on electricity, and value addition by major and minor crops in agricultural output are utilized, corroborated by field surveys of selected farm samples. Additional losses due to disruption of rural household activities, based on value addition by economic activities (dairy, poultry, handicraft, etc.) and surveyed willingness-to-pay data, have been assessed recently to arrive at the total cost of power outages for the agricultural sector.

4.1.2. ECONOMIC IMPACTS

Virtually all productive economic sectors of the economy depend on electricity as an indispensable input required for value addition. Apart from its necessity for running industrial, commercial, agricultural, and domestic equipment, machinery and lighting, it also serves to be an important factor in the productivity of human capital. Apart from its use in powering production processes and commercial services, electricity is also required for the proper storage of raw materials and some finished products, and interruptions in electricity supply therefore can result in business losses, increased costs, and reduced profitability at a minimum to the closure of factories, loss of markets, and unemployment, depending on the scale and frequency of such outages. Multiplier effects of such direct impacts on one sector on other segments of the economy as well as various indirect effects can amplify outage costs and the resultant losses to the national economy. Studies have extensively documented the association between electricity, economic productivity, and the entailing contribution to the GDP (**Section 4.1.1**).

In order to evaluate the economic impacts of USAID's LDI intervention, relevant detailed studies carried out in the past for the impact of load shedding on Pakistan's economy were consulted and adapted to develop an analytical framework for the quantification of outage-related losses in the main economic sectors:

- Large and small industry
- Commercial services
- Domestic and residential
- Agriculture

The updated outage cost factors calculated were then applied to the direct impacts of the LDI project on the power supply metrics calculated in **Section 3** to assess any resulting economic benefits at the national level. Pasha [2013], the most recent detailed analysis carried out for all sectors, was used as the primary basis for computing the economic cost of outages (i.e., $/kWh) pertaining to each sector as well as, in some instances, subcategories within each sector. The underlying factors on which such costs depend were updated to the current year (2014), where possible, or reasonable assumptions made where current information (such as consumer behavioral responses and reported losses based on representative surveys) was not available. It should be mentioned that Pasha [2013] does not quantify the economic costs of load shedding for large-scale industries, and instead aggregates values for this sector taken from a previous study, Pasha [2009], with his calculations for the small-scale industrial sector to obtain the cost of power outages for the industrial sector as a whole. The Pasha [2009] study, also carried out for large-scale industry, was unavailable and therefore could not be directly consulted here. Furthermore, Pasha [2013] does not distinguish between the relative impacts of unplanned versus planned load shedding. This was done previously for the industrial sector by Pasha [1989], whose findings have been adapted for this study to distinguish similar differential load shedding impacts in other sectors as well, as applied to the current economic data, which was largely derived from the Economic Census of Pakistan and the Pakistan Economic Survey published by the GOP.

As can be seen from

Exhibit 4.3, power outage impacts assessed for each economic sector by Pasha [2013], when compared to the average corresponding values reported in previous international studies listed in

Exhibit 4.1, are consistently much lower. This is possibly due to the fact that the international estimates include impacts in more developed economies with much higher per capita electricity consumption rates (see, for instance, **Section 4.1.3** for a discussion of the relationship between economic development and electricity consumption), where power outages are expected to therefore, be more disruptive and comparative factor costs are much higher than in Pakistan. It can nonetheless be argued that the economic impact basis used to evaluate the impact of the LDI project in this study is a conservative one, with a correspondingly low probability of overestimation in terms of the estimated quantitative monetary benefits summarized in **The results** of this analysis are presented in Error! Not a valid bookmark self-reference.. Total annual direct cost savings of Rs 18.1 billion ($178.1 million) have thus been estimated for the national economy due to the LDI project's impact on unscheduled load shedding practices, compared to the total impact of load shedding on the national economy in 2013 estimated by Pasha [2013] at Rs 14.4 trillion ($14.3 billion) shown in **As can** be seen in

Exhibit 4.6 and

Exhibit 4.7, the impact of LDI is proportionately highest for the industrial sector, with a loss reduction of 5.1% affected by a reduction in unplanned outages. This estimated annual economic benefit of the LDI project of approximately $179.9 million also compares favorably with its implementation cost of $3.7 million.

Exhibit 4.5, given that the total load shedding amount has not changed in the pre- and post-LDI periods. To these benefits, a multiplier of approximately 3% is applied to arrive at an aggregate direct and indirect benefit of the LDI project of Rs 18.27 billion ($179.9 million) for the Pakistani economy purely from the near-elimination of unplanned load shedding in the country. These savings represent a 1.3% reduction in the overall national outage costs computed by Pasha [2013] of Rs 1,439 billion ($16 billion) for the year.

Exhibit 4.4 below.

Data pertaining to national power generation, load demand, scheduled and unscheduled load shedding, and other operational parameters for the national grid was analyzed to quantify the effect of LDI intervention on the overall power supply-demand balances and the magnitude of unscheduled load shedding over comparative pre- and post-LDI months during 2012-2014. The only quantifiable direct impact of the LDI project on power system operations was assessed to be a reduction in total unscheduled load shedding of 1,805 GWh over the year from July 2013 to June 2014 (**Section 3.3.2**). Therefore, this reduction in unplanned load shedding was allocated to the industrial, agricultural, domestic and commercial classes of consumers based on their respective average load shares on the national grid, using the most up-to-date information available for the period of July to December 2013.[27]

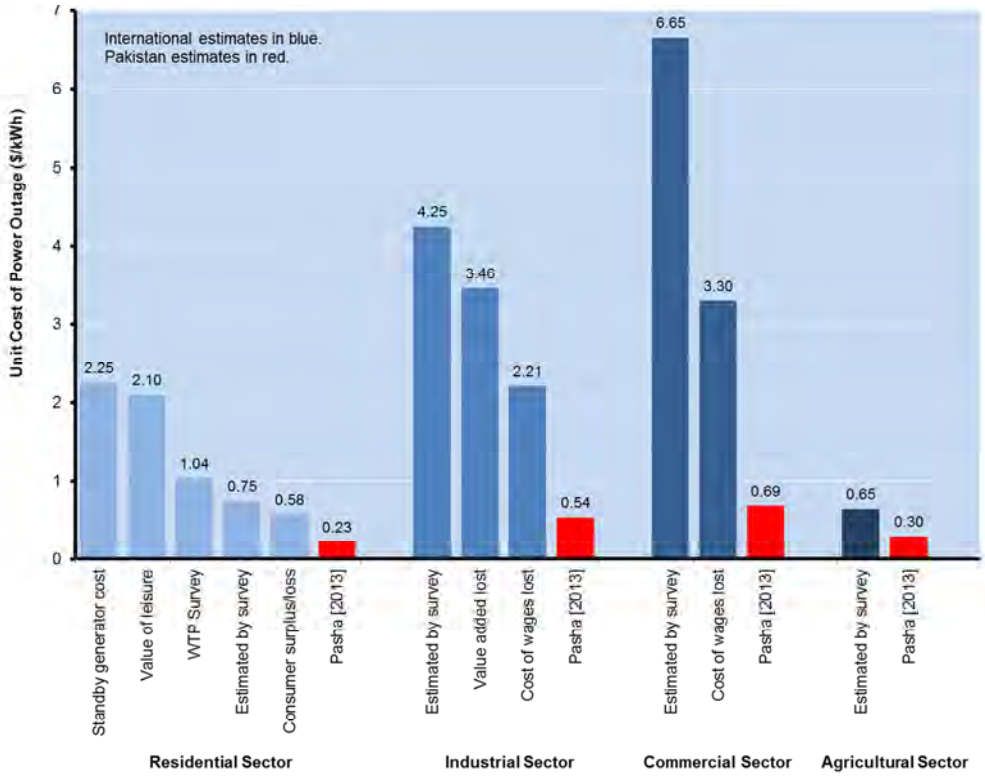
Analysis of the pre- and post-LDI grid performance and operational data over the study period indicates a significant decrease in unscheduled load shedding, including average monthly total megawatts curtailed, outage duration and frequency, and undelivered energy, while the amount of total load shedding, a function of the overall power supply-demand imbalances on the grid due to national infrastructure constraints, remained roughly the same for both periods. For quantifying the economic impact, it has been assumed that this reduction in unscheduled load shedding is entirely attributable to the LDI intervention, as discussed earlier in **Section3.3.2**. A spreadsheet-based calculation was employed in this study to compute the economic benefits of the LDI project for each economic sector resulting from the evaluated reduction in unscheduled load shedding across the grid, extrapolated from the study period of seven months (July 2013 to February 2014) to arrive at annual impacts (details of the calculation methodology are provided in **Appendix A**, while the calculation spreadsheets are included in **Appendix B**). For this purpose, a differentiation between the costs resulting from unscheduled and scheduled load shedding is required. As a rule, the cost of unscheduled load shedding is assumed to be higher due to several factors, including the reduced ability of consumers to adjust to the outage, increased spoilage, increased idle factor costs due to unavoidable shutdowns, higher damage to

[27] WAPDA [2011-13].

operational equipment and processes suddenly disrupted, etc. This is supported by detailed independent studies previously conducted on the economic impact of power outages.[28] Thus, the quantifiable direct economic impact of a reduction or elimination of unscheduled load shedding, even with the overall amount of load shedding in the system remaining the same, is expected to be positive.

[28] For instance, Pasha [1989] computed the impact of unplanned outages on the industrial sector to be 76% higher than that of planned outages ($0.67/kWh and $0.38/kWh, respectively, in nominal terms).

Exhibit 4.3: Comparison of International and Pakistan Estimates of Power Outage Impacts



However, existing Pakistan-specific analyses of outage costs by economic sector, based on actual survey samples to compute Rs/kWh losses disaggregated into distinct cost components relevant to each sector, provide only total losses attributable to the load shedding regime prevalent at the time, which invariably consisted of both scheduled and unscheduled load shedding. The only exception to this is Pasha [1989], in which the costs to large-scale industry have been computed separately for both scheduled and unscheduled power outages. For the purpose of this study, while the outage cost differential between scheduled and unscheduled load shedding can thus be derived by updating the base assumptions of Pasha [1989] to the current timeframe, a different approach had to be devised to estimate this differential for the other sectors to be able to arrive at the overall impact of the LDI project at the national level.

Briefly, for all sectors other than the industrial sector, the cost drivers for each sector's total outage costs have been examined to determine which would be significantly impacted by unscheduled load shedding compared to scheduled load shedding. A conservative multiplying factor is then assumed to determine the increase in that component, due to unscheduled load shedding, and using the proportion of scheduled vs. unscheduled load shedding prevailing during the timeframe of the Pasha [2013] study together with the total outage cost, the ratio or differential between unscheduled vs. scheduled outage cost for that sector can be calculated.

This approach, of course, is dependent on the choice of the inflationary multiplier used, which is based both on reasoned logic as well as a quick sensitivity analysis of the overall resulting economic costs on an appropriate range for the multiplier. The resulting cost ratio of unscheduled to scheduled load shedding for each sector is also compared with that reported by Pasha [1989], which is taken as an upper bound and used to correct the assumed multiplier, if necessary.

In this manner, the differential costs between the impact of planned vs. unplanned load shedding have been calculated for each sector as described below, with further elaboration provided in **Appendix A**, and then applied on the impact of the LDI project on the two load shedding categories derived earlier. The actual quantifiable impact spreadsheet calculations are included in **Appendix B**.

4.1.2.1. INDUSTRIAL SECTOR

Pasha [1989], in the most comprehensive study of outage costs for large- and small-scale industries in Pakistan to date, computes sector impact costs per unit of load shed separately for planned and unplanned load shedding for the country's industrial sector, based on the total outage cost and unit of electricity not delivered for different categories and subcategories of industries, based on a representative surveyed sample which is then extrapolated to the national level using overall industrial sector statistics. In the absence of more recent such analysis distinguishing between the costs of scheduled vs. unscheduled load shedding, this study applies the 1989 cost ratio to the most recent sector outage cost figures reported for the industrial sector in Pasha [2013]. The overall costs to the industrial sector and its subcategories, in terms of Rs/ kWh, were thus recalculated for both unscheduled and scheduled load shedding in the current (2012-2014) context, and the differential between them was used to impute the additional burden of unscheduled load shedding, which was found to be Rs 30.70/kWh.

4.1.2.2. DOMESTIC SECTOR

For the domestic sector, the estimation of outage cost differential between scheduled and unscheduled classes of load shedding has been inferred using the method described previously, as only the total combined load shedding costs are provided in Pasha [2013]. As described by Pasha [2103], overall outage costs to domestic consumers can be differentiated into the monetization of utility loss, adjustment costs (e.g., standalone generators and UPSs), and other costs (e.g., spoilage and lost income). While costs accruing from "utility loss" and "adjustments" to both types of outages can be assumed to be roughly the same (in reality, unscheduled outage costs for these categories would be slightly higher), "other costs", which consist of spoilage costs, damage to appliances, lost income from productive household employment, etc., should be discernibly higher in the case of unscheduled load shedding. For estimation purposes, therefore, a conservative factor of 25% was applied only to this outage cost component in the overall load

shedding cost for the domestic sector reported in Pasha [2013], and the resulting differential between scheduled and unscheduled load shedding calculated to be Rs 0.74/kWh for this sector.

4.1.2.3. COMMERCIAL SECTOR

Similarly, for the commercial sector, individual cost components of the sector losses accruing from load shedding, as defined by Pasha [2013], have been assessed to attribute any additional impact of unscheduled outages over scheduled impacts. “Net idle factor” costs, the cost of the foregone output resulting from unscheduled outages, and “spoilage” costs are both assumed to be inflated upwards by a factor of 25% in the case of unscheduled load shedding, and the required cost differential with scheduled load shedding calculated at Rs 12.1/kWh.

4.1.2.4. AGRICULTURAL SECTOR

Electricity consumption in the agricultural sector, in terms of economic value addition, is dominated by the use of tube wells and to a lesser extent by productive household activities, such as dairy production. Given that actual total non-load shedding hours in a day are generally more than the average daily duty cycles of agricultural electric tube wells, and tube well use is not time-critical, it can be assumed that the incremental impact of the elimination of the roughly 10% unscheduled load shedding, with overall load shedding amounts unchanged, will not substantially impact agricultural sector output as farmers can easily adjust their irrigation practices over a 24-hour or an even longer period. Therefore, the cost differential between scheduled and unscheduled load shedding for the agricultural sector is taken to be negligible.

These differential costs per kWh calculated for each sector above were applied as the incremental cost of unscheduled over scheduled load shedding to the reduction in unscheduled load shedding resulting from the implementation of the LDI project, as allocated to the corresponding sector out of the overall 1,805 GWh annual reductions in unplanned load shedding described earlier. In this context, these sector-specific avoided cost figures represent the overall direct economic benefit accruing to each sector and the economy as a whole as a result of the LDI project over the first year of its operation which has resulted in a drastic reduction of unplanned load shedding in the country.

The results of this analysis are presented in Error! Not a valid bookmark self-reference.. Total annual direct cost savings of Rs 18.1 billion ($178.1 million) have thus been estimated for the national economy due to the LDI project’s impact on unscheduled load shedding practices, compared to the total impact of load shedding on the national economy in 2013 estimated by Pasha [2013] at Rs 14.4 trillion ($14.3 billion) shown in **As can** be seen in

Exhibit 4.6 and

Exhibit 4.7, the impact of LDI is proportionately highest for the industrial sector, with a loss reduction of 5.1% affected by a reduction in unplanned outages. This estimated annual economic benefit of the LDI project of approximately $179.9 million also compares favorably with its implementation cost of $3.7 million.

Exhibit 4.5, given that the total load shedding amount has not changed in the pre- and post-LDI periods. To these benefits, a multiplier[29] of approximately 3% is applied to arrive at an aggregate direct and indirect benefit of the LDI project of Rs 18.27 billion ($179.9 million) for the Pakistani economy purely from the near-elimination of unplanned load shedding in the country. These savings represent a 1.3% reduction in the overall national outage costs computed by Pasha [2013] of Rs 1,439 billion ($16 billion) for the year.

Exhibit 4.4: Estimated Annual Economic Benefits Resulting from LDI Implementation in 2013

Sector/Benefit	Total Cost of Outages	Incremental Cost of Unscheduled Outages	Reduction in Unplanned Load Shedding	Annual Loss Reduction Resulting from LDI Project		LDI Impact on Annual Outage Losses
	Million Rs	Rs/ kWh	GWh	Million Rs	Million $	
Direct Savings						
Industrial	314,000	30.68	518	15,885	156.5	–5.1%
Commercial	472,000	12.10	123	1,491	14.7	–0.3%
Domestic	240,000	0.60	954	709	7.0	–0.3%
Agriculture	89,000	0.0				0%
Total Direct Savings	**1,115,000**			**18,805**	**178.1**	**–1.7%**
Indirect Savings	324,000			185	1.82	–0.1%
Total	**1,439,000**		**1805**	**18,270**	**179.9**	**–1.3%**

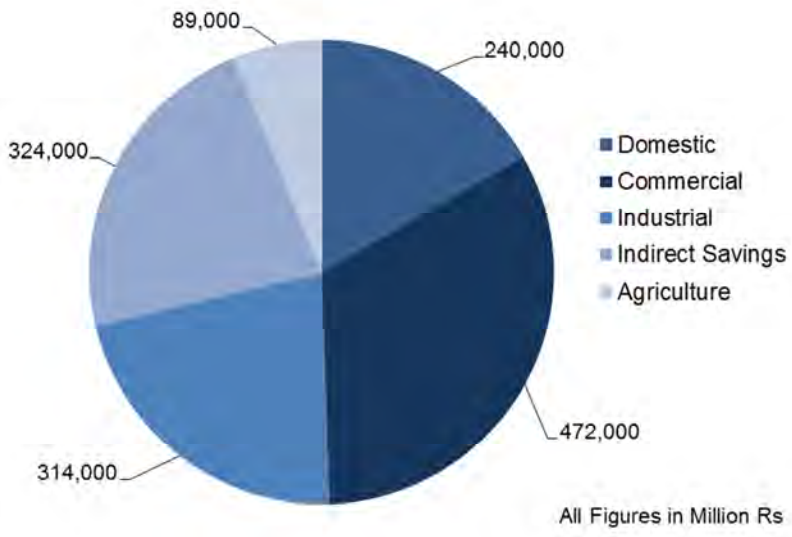
As can be seen in

Exhibit 4.6 and

[29] Derived from the 37% taken by Pasha [1989] and [2013] as the indirect effect of total large-scale industry sector outages on all other sectors of the economy, and adjusted for the actual proportion of unscheduled to total load shedding in 2013 (28%) and the ratio of differential-to-total cost to industry of scheduled and unscheduled load shedding (27.8%) given in Pasha [1989].

Exhibit 4.7, the impact of LDI is proportionately highest for the industrial sector, with a loss reduction of 5.1% affected by a reduction in unplanned outages. This estimated annual economic benefit of the LDI project of approximately $179.9 million also compares favorably with its implementation cost of $3.7 million.

Exhibit 4.5: Total Losses Due to Load Shedding in Pakistan by Sector 2013



Source: Pasha [2013].

Exhibit 4.6: Reduction in Load Shedding Losses as a Result of LDI by Sector, 2013

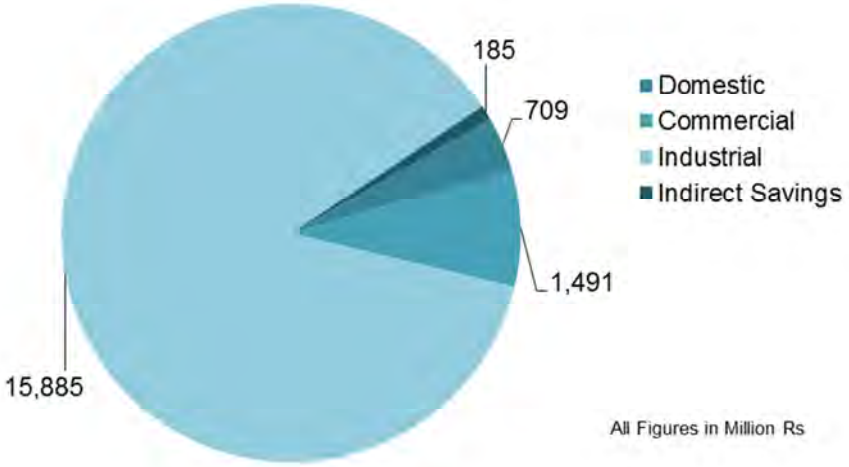
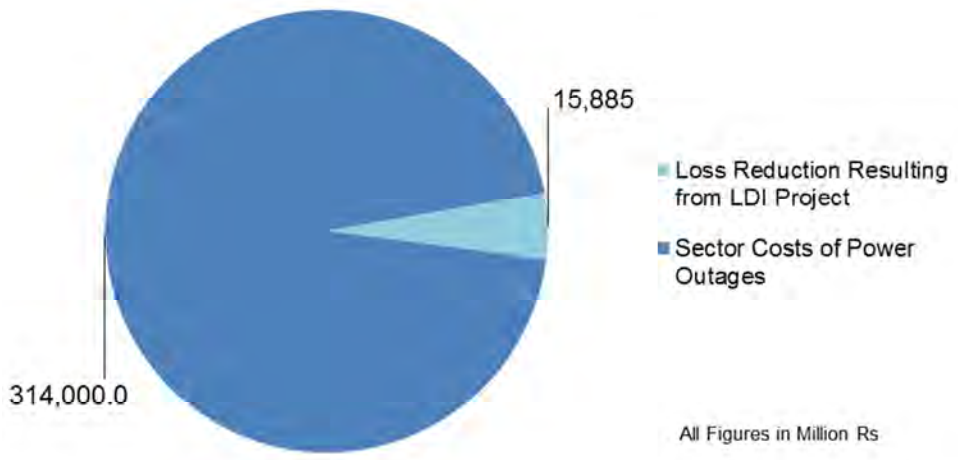


Exhibit 4.7: Impact of LDI on Industrial Sector Outage Costs



4.1.3. SOCIAL IMPACTS

Access to modern energy services (as distinct from the open combustion of biomass fuels and kerosene), including electricity and other fuels (e.g., natural gas, liquid petroleum gas (LPG), petrol and diesel), is an essential requirement of modern societies and necessary to maintain the minimum acceptable standards of living. In particular, electricity, because of its versatility and widespread availability and use, is considered critical for all sectors of a modern economy as well as households and individuals. Access to electricity is contingent upon both the supply of adequate amounts of generated power and the provision of associated T&D infrastructure for delivery to end users, as well as its affordability, as measured by retail electricity tariffs (net of any subsidies and taxes) as a proportion of average individual or household income levels.

The social benefits of affordable, readily accessible electricity to all citizens are innumerable, from the knock-on effects on general prosperity, consumer choices, and quality of services made possible by the overall growth of the main economic sectors (industry, agriculture, commercial and retail sectors, etc.) as enumerated in the previous section, to the direct impact on individuals' well-being resulting from better living conditions and amenities made possible by electricity (lighting, space conditioning, refrigeration, television and information and communications technology (ICT), etc.), as well as the provision of essential and effective social services (healthcare, education, water supply, etc.) necessary for the attainment of acceptable standards of living.

4.1.3.1. CUMULATIVE HUMAN DEVELOPMENT IMPACT

While it is difficult to quantify these numerous, interdependent impacts separately, an overall assessment of the impact of electricity use with social attainment can be inferred. For instance, the link between access to modern energy services and human development is obvious and very strong, and the empirical evidence supporting this has been extensively studied and documented internationally. In particular, the relationship between electricity consumption per capita and the human development index (HDI)[30] has been found to be strongly correlated. The HDI, compiled and published annually by the United Nations for its member countries, is a useful standardized measure of "human development" for comparative purposes that takes into account life expectancy, education, and standard of living (through per capita income) that is not derived primarily from economic or energy use statistics but also assesses the ability of citizens to pursue individual choices that can result in productive, creative and contended lives.

Actual HDI values as reported by the UN for different countries plotted against their respective annual per capita electricity consumption (u) shows a strong correlation along a rapidly rising curve that then flattens out (

[30] The HDI is a composite index that measures a country's average achievements in three basic dimensions of human development: a long and healthy life, as measured by life expectancy at birth; knowledge, as measured by the adult literacy rate and the combined gross enrolment ratio for primary, secondary and tertiary schools; and a decent standard of living, as measured by GDP per capita in purchasing power parity (PPP) US dollars.

Exhibit 4.8).[31] As is evident from the diagram and from detailed investigation of the relationship between the two factors, it appears that there is an approximate threshold of 4,000 kWh/capita, corresponding to an HDI value of about 0.9, taken as a minimum threshold value for "developed" societies. Beyond this, the plotted trend plateaus, indicating that the impact of additional electricity supply on the standard of living lessens considerably above 4,000 kWh/capita. Many developing countries have progressed up the steep end of the curve, although very few have managed to cross the 4,000 kWh/capita threshold. Nevertheless, developing countries stand to gain disproportionate increases in their HDI rankings, and therefore their citizens' social well-being, by achieving even small increases in their per capita electricity use.

Pakistan, with its average of 366 kWh/capita of electricity consumption and a corresponding HDI of 0.515 in 2012, as shown by the red marker in the exhibit, is clearly amongst countries poised to reap substantial human development benefits if it can increase the access of its population to electricity, as it is still on the vertical end of the HDI-u curve.[32] Using the empirical HDI-u relationship shown in red in

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31 Originally conceived by Pasternak [2000], Garcia [2006] refined the relationship between HDI and u, the per capita electricity consumption in kWh, in the form HDI = $\tanh[(u/u_o)^{0.25}]$, where u_o = 1,400 kWh/capita is a normalization factor, and reinforced the inflexion point at 4,000 kWh/capita, corresponded to an HDI of 0.862, based on 2005 data for 177 countries. In

Exhibit 4.8, adapted from Masud [2007], the HDI-u curve is plotted along with 2002 country data for 171 nations, with a datum point for Pakistan for 2012 added for reference.

32 Although the HDI-u curve in the figure is based on 2002 world data in Masud [2007], the functional relationship between per capita electricity consumption and HDI does not change, and countries move up along the curve as their electricity use increases. Thus, the curve remains constant, and can be used for data for other years, as shown in the case of Pakistan for 2012.

Exhibit 4.8, i.e., HDI = $\tanh[(u/u_o)^{0.25}]$, where u_o = 1,400 kWh/capita is a normalization factor, it is possible to compute the potential impact of a change in the annual per capita electricity availability on the country's overall HDI rating (i.e., △HDI).

Given the current data resolution constraints, however, it is not possible to reliably assess the additional generation in MW made available to the national grid purely on account of the implementation of the LDI project, e.g., through reduced spinning reserve requirements (see **Section 3.1.2**). If such an amount can be verified, it would be possible to deduce the resulting improvement in the HDI value for the country as a whole from the additional power supplied to consumers. Such a △HDI would be small, but possibly discernible given its extreme sensitivity to per capita electricity use changes in the portion of the HDI-u curve that currently applies to Pakistan.

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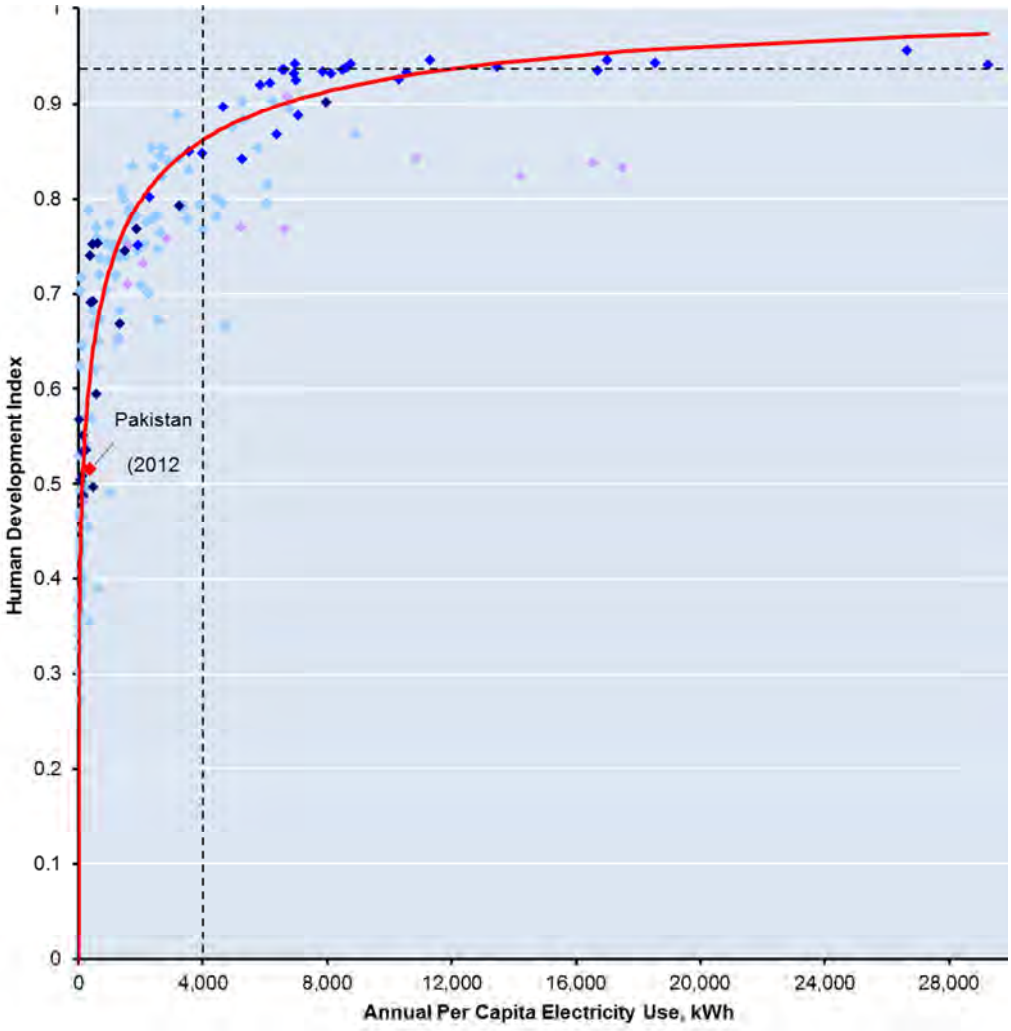
Exhibit 4.8: Human Development Index and Electricity Use



Additionally, by helping improve the overall health of Pakistan's power sector and facilitating future investments and capacity growth, as described in **Section 5**, the LDI project's ultimate impact on social welfare as measured by the HDI index is expected to be greater. This translates into improved living conditions, productivity, employment and incomes, and the delivery and impact of social services, such as education, healthcare, water supply, ICT, etc. The attainment of the Millennium Development Goals (MDGs) by 2015, as undertaken by the developing member countries of the UN, including Pakistan, also requires greater access in terms of supply and affordability of electricity by all citizens, as each of the eight MDGs depends critically on the provision of power for the underlying services and facilities to be functional (e.g., medical equipment in hospitals and clinics, lighting and computers in schools, pumping for piped water, etc.).

An increase in the HDI translates into a population and workforce that is better educated and healthier, thus boosting the overall GDP growth rate of the national economy, industrial and agricultural productivity, export competiveness, and so forth. These national level gains, although not easily quantifiable, would be additional to the direct and multiplier impacts on these factors on account of more reliable electricity supply and reduced outages computed earlier in **Section 4.1.2**.

4.1.3.2. ENVIRONMENTAL BENEFITS

Net additions to power supply utilizing existing generation capacity through better load prediction, monitoring and dispatch afforded by the LDI project, if any, would also result in a number of environmental benefits, such as the reduction in equivalent additional thermal power generation which would help reduce local atmospheric pollution (particulates, NO_x and SO_x emissions) as well as carbon emissions in the form of greenhouse gases (CO_2, N_2O, and CH_4 emissions). Improved electricity access can also partly replace the unsustainable harvesting or hazardous combustion of alternative primary biomass fuels (firewood, dung, etc.), which can help reduce associated environmental degradation, healthcare costs and unproductive labor, and thereby alleviate poverty pressures.

4.2. POWER SECTOR LEVEL IMPACTS

4.2.1. IMMEDIATE IMPACTS

The immediate impacts of the LDI project on the power sector have been detailed in the preceding discussion in terms of improvement in the management of supply-demand imbalances on the NTDC system, almost complete elimination of unplanned load shedding (except in extenuating circumstances), improved detection of theft and resultant loss reduction, and the resultant expected impact on the economic dispatch of power based on aggregated technical and commercial (AT&C) losses, which can lead to increased utility billing and revenues.

This is expected to improve the overall operational and financial performance of the DISCOs, and enable them to improve service delivery and better plan their future expansion (see **Section 4.3**).

4.2.2. LONGER TERM IMPACTS

In addition to the immediate and near-term impacts of the LDI project on improvement in DISCO performance and financial earnings, the LDI project can also facilitate the longer term development of Pakistan's power sector by helping power sector entities attain achieve

international best practices and financial and operational credibility in the eyes of local and foreign investors.

These longer term potential benefits of the LDI project are described in **Section 5**, and include facilitation of power sector reforms and restructuring milestones, operationalization of a wholesale power trade market (i.e., via the CPPA), privatization of power distribution utilities, improved grid planning and investments, and improved investment outlook for the power sector for future expansion needs across the generation, transmission, and distribution sectors vis-à-vis international financing institutions, commercial banks, and overseas and local private equity.

4.3. UTILITIES LEVEL IMPACTS

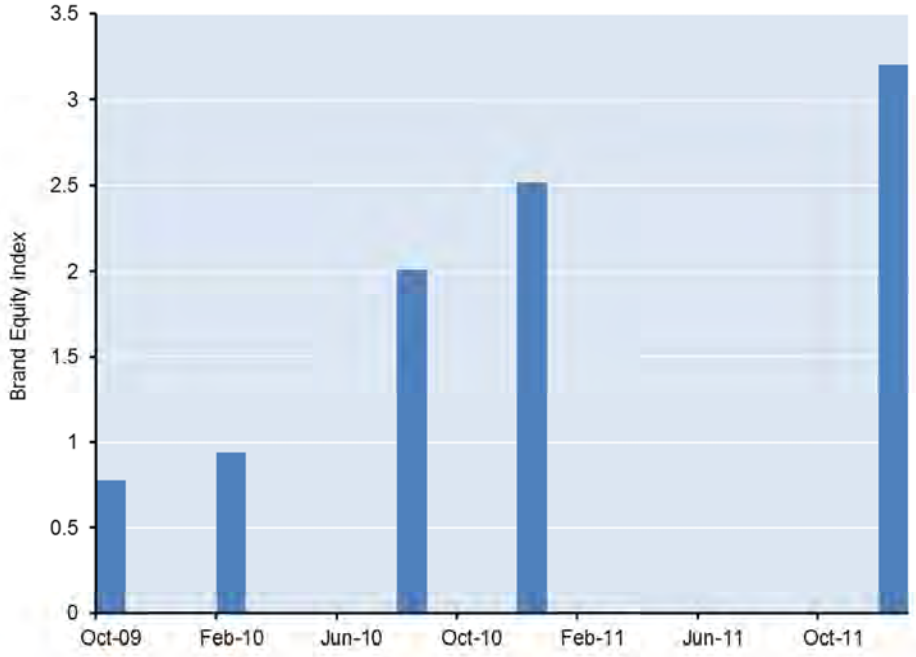
Improved system efficiency, service delivery, Key Performance Indicators (KPIs), etc., reduction in response and down times on account of emergencies, contingencies, maintenance, and fault correction as a result of availability of real-time network data, and improvement in power supply quality (e.g., voltage, frequency, power factor, etc.) is expected in the short- to medium-term as DISCOs become better accustomed to utilizing system-wide LDI-generated data to analyze grid load patterns, feeder performance, consumer load profiles, and undertake better dispatch planning and service and revenue optimization schemes. This is expected to raise consumer satisfaction levels, increasing their willingness to pay for reliable, uninterrupted power supplies, as well as help utility management and staff in daily system maintenance, bill collection, and theft detection. A positive change in customer attitudes would also help facilitate further service and revenue enhancement measures, such as differentiated tariffs, smart grids, and online customer servicing.

The example of the privatized, vertically-integrated utility, K-Electric (formerly the Karachi Electric Supply Company), is very relevant in this respect. As a result of improved load management practices enabled by AMR installations which helped reduce forced load shedding and the implementation of AT&C-based dispatch practices, along with a variety of other related customer service improvements (such as prompt fault correction, complaint responsiveness, and better access to planned load shedding schedules), in recent years K-Electric has witnessed a significant positive trend in its customer satisfaction surveys, power theft reporting, and willingness to pay for better and more reliable electricity supply. These measures have enabled K-Electric to ensure uninterrupted supply of electricity (zero load shedding) to industrial customers in its service area starting in 2009, to become the first Pakistani utility to introduce “fixed load shedding” (zero unscheduled load shedding) for all other customers, to implement zero load shedding for all customers on Sundays and national holidays, and to exempt 55% of Karachi city altogether from load shedding. This approach helped K-Electric establish a correlation between power theft and load shedding duration which in turn has helped reduce the company’s distribution losses to 29.7% in 2012 (from 35.9% in 2009), the lowest in the last 18

years. To supplement these gains, K-Electric's corporate social responsibility initiatives have centered around stakeholder engagement, social investment programs and thought leadership, and allow the utility to connect with its consumer base at the grassroots level. The campaigns launched not only help convey service concerns expressed by consumers to the utility's management, but also allow K-Electric to communicate its load management and consumer-satisfaction enhancement strategies more effectively to its customers (through, for instance, the establishment of dedicated service-oriented 118 Call Centers and Integrated Business Centers). The DISCO has also launched loss reduction initiatives—such as "Speak Up", the "Name and Shame" campaign, and specific locality-based anti-theft drives—which involve grassroots mobilization of its various consumer categories. These initiatives, launched in tandem with an active consumer outreach program through the electronic, print and social media, have augmented the firm's improved power-delivery performance obtained through information technology IT-enabled load management practices (similar to LDI) and have resulted in an improvement of the company's Brand Equity Index (BEI) from a level of 0.78 in October 2009 to 3.2 in December 2011. The BEI is an international benchmark, which gauges the value of a firm's brand,[33] has been demonstrated to have a positive association with customer willingness-to-pay. Therefore, it can be surmised that the positive trends in the K-Electric's perceived brand value, resulting from improved load management and service delivery, can be linked to an increased customer willingness-to-pay for electricity. This is further corroborated by the firm's improved revenues in recent years, resulting in part from enhanced bill recovery (collections improved by 95% in areas consuming two thirds of total energy supplied), with the utility recording its first profit in 17 years in FY 2012.

[33] 'Brand equity' can be defined as the power derived from the goodwill and name recognition that a brand has earned over time translating into higher sales volume and higher profit margins.

Exhibit 4.9: Enhancement in K-Electric's Brand Equity Index Resulting from Improved Load Management and Customer Service Delivery



There is therefore a compelling case for the DISCOs to also institute AT&C-based load shedding not just to improve their financial viability, but also to help build social pressure against electricity theft and improve customer perception of service reliability and willingness to pay. The argument that this will unfairly penalize "good" or paying customers in badly performing regions will be rebutted over time if appropriate measures are taken to protect the identity of theft reporters and the utility takes prompt actions to effectively curb electricity theft, as evidenced in the experience of K-Electric, where active AT&C-based load management (including remote disconnection of defaulting customers), aggressive public campaigning, anonymous theft reporting mechanisms, and quick complaint rectification measures have helped turn an extremely troubled utility completely around, with two-thirds of its operations now reporting 94% recovery rates, moderate to low (<18%) losses, and contributing 78% of total revenues while consuming only 69% of the electricity provided, encouraging the company to now move into implementing even more effective smart grid operations on a pilot scale. The new law on electricity theft recently passed by the national parliament can also be helpful in sustaining loss reduction drives in concerned areas and helping improve utility recovery rates that can eventually be useful in further reducing load shedding and improving grid performance.

4.3.1. REVENUES

Better load management practices made possible by the LDI project, such as the elimination of unnecessary forced outages, prioritization of feeders with low AT&C losses, a possible reduction in system spinning reserve margin requirements (if any), and greater customer willingness-to-pay for the resulting improved service delivery can translate into enhanced revenues and cash flows for power utilities. These interrelated benefits have been borne out in international utility practice, as well as recently by the K-Electric experience in Pakistan recounted above. These gains can not only enable DISCOs to allocate greater funds for grid O&M and system expansion investments, but also reduce the need for significant federal tariff differential subsidies (TDS) that are currently being provided to keep electricity tariffs within an affordable range for low-income consumer categories. Enhanced revenues and cash flows for DISCOs would therefore directly help improve their financial health, reduce the circular debt in the power sector, alleviate the burden on the national exchequer, and improve private investor confidence in undertaking new projects, especially in badly needed generation expansion as well as the privatization of DISCOs.

There can be several factors affecting total DISCO sales revenues, with the major ones being:

- Changes in the amounts of power supplied by NTDC to the DISCO (presently, quota-constrained)
- Changes in distribution priority (e.g., AT&C-based load shedding)
- Changes in distribution losses (both technical and non-technical)
- Changes in retail electricity tariffs
- Changes in customer base and consumption profiles

It is convenient for this discussion to introduce a general classification of the DISCOs. Based on their respective T&D losses, bill recovery rates and utilization of allocated power, the DISCOs can be broadly grouped into two categories: “Group A,” or the better performing DISCOs (i.e., LESCO, IESCO, FESCO, GEPCO and MEPCO), typically having lower T&D losses, higher collection rates and higher power quota utilization rates (with a likelihood of excessive demand, demonstrated by frequent overdrawing of supply from the national power pool); and “Group B,” or underperforming DISCOs (i.e., QESCO, PESCO, SEPCO, HESCO and TESCO), with relatively high T&D system losses on account of pilferage and poor infrastructure, poor bill recovery rates and low average consumer ability to pay, leading to self-imposed load shedding necessitated by these constraints which generally results in under-drawing of power from their NPCC-allocated quotas.

Of the elements listing above that can affect utility revenues, LDI could potentially impact only the first three, while the last two are independently determined. In the first three cases, enhanced LDI-enabled network load data and grid management could enable:

- The NTDC to reallocate inter-DISCO power allocation quotas from underperforming Group B DISCOs to better performing Group A DISCOs, thereby improving the productive and efficient use of available power in the national pool while increasing overall DISCO revenues due to higher average retail tariffs in Group A DISCOs (i.e., implement economic dispatch of power, to the extent that Group B DISCOs under-draw from their initially allocated shares). Note that such power transfers would not, of course, result in an increase in overall power supply which is affected only by changes in the generation (capacity additions and plant availability).
- Further optimize intra-DISCO power dispatch to reduce load shedding on better performing (higher tariff and bill recovery basis), thereby increasing sales revenues from a given amount of power sold (AT&C-based dispatch).
- A reduction in distribution losses (primarily theft and pilferage, as well as overloaded feeders and transformers) resulting from AT&C-based dispatch, increasing the amount of saleable power.

The following discussion summarizes the financial performance of the DISCOs during the pre- and post-LDI periods, assessing the overall impact of the factors enumerated above. Although it is not possible to assess the impact of LDI on the last two factors (i.e., AT&C-dispatch gains), optimization of inter-DISCO power reallocation has been estimated below and the net financial benefit thus derived estimated. The overall financial performance of DISCOs is also assessed for both the pre- and post-LDI periods.

4.3.1.1. FINANCIAL IMPACT OF OPTIMIZED INTER-DISCO POWER REALLOCATION

The instantaneous access to key power sector information at the DISCO and national levels afforded by LDI have allowed the NPCC to optimize power supply allocations to DISCOs. NPCC has historically been redirecting untapped power from Group B utilities to Group A DISCOs in order to maximize the economic utilization of total available generation. However, it is expected that the availability of real-time data on DISCOs system demand and loads, courtesy of the LDI project, would enable the NPCC to reallocate power quotas more optimally than was possible in the pre-LDI days, thus resulting in additional financial and economic gains. At a minimum, this would result in some of the underutilized Group B quota to serve higher paying customers or higher collection regions in Group A DISCOs, thereby increasing the aggregated financial revenues from power sales in the country while reducing the subsidy burden on the government on account of low average Group B revenue per unit. This would also help improve the financial

position of Group A DISCOs by increasing their revenue streams, allowing them to further enhance their service, maintenance, and system investments.

Table 1 of the accompanying spreadsheet (**Appendix B.2**: Inter-DISCO Reallocation Computation) illustrates the analysis of hourly data for load demand, NPCC allocation, actual load drawn and the difference between load drawn for the nine DISCOs as well as K-Electric for the period November 1, 2013 to February 28, 2014 (selected to match the availability of hourly NPCC generation data, which is adjusted to account for losses of 5.24% in the transmission system up to the DISCOs' 11 kV bus bars[34]). The difference between the NTDC allocated quotas and actual load drawn for the post-LDI period of July 2013-April 2014 is shown in

[34] Computed by including energy losses in the NTDC network as well as in DISCO 132kV system for the period 2012-2013.

Exhibit 4.10,[35] which demonstrates that Group A DISCOS largely utilize their full quotas, while Group B DISCOs (especially PESCO and QESCO, and to a lesser extent HESCO and MEPCO) under-draw their quotas during much of this period.

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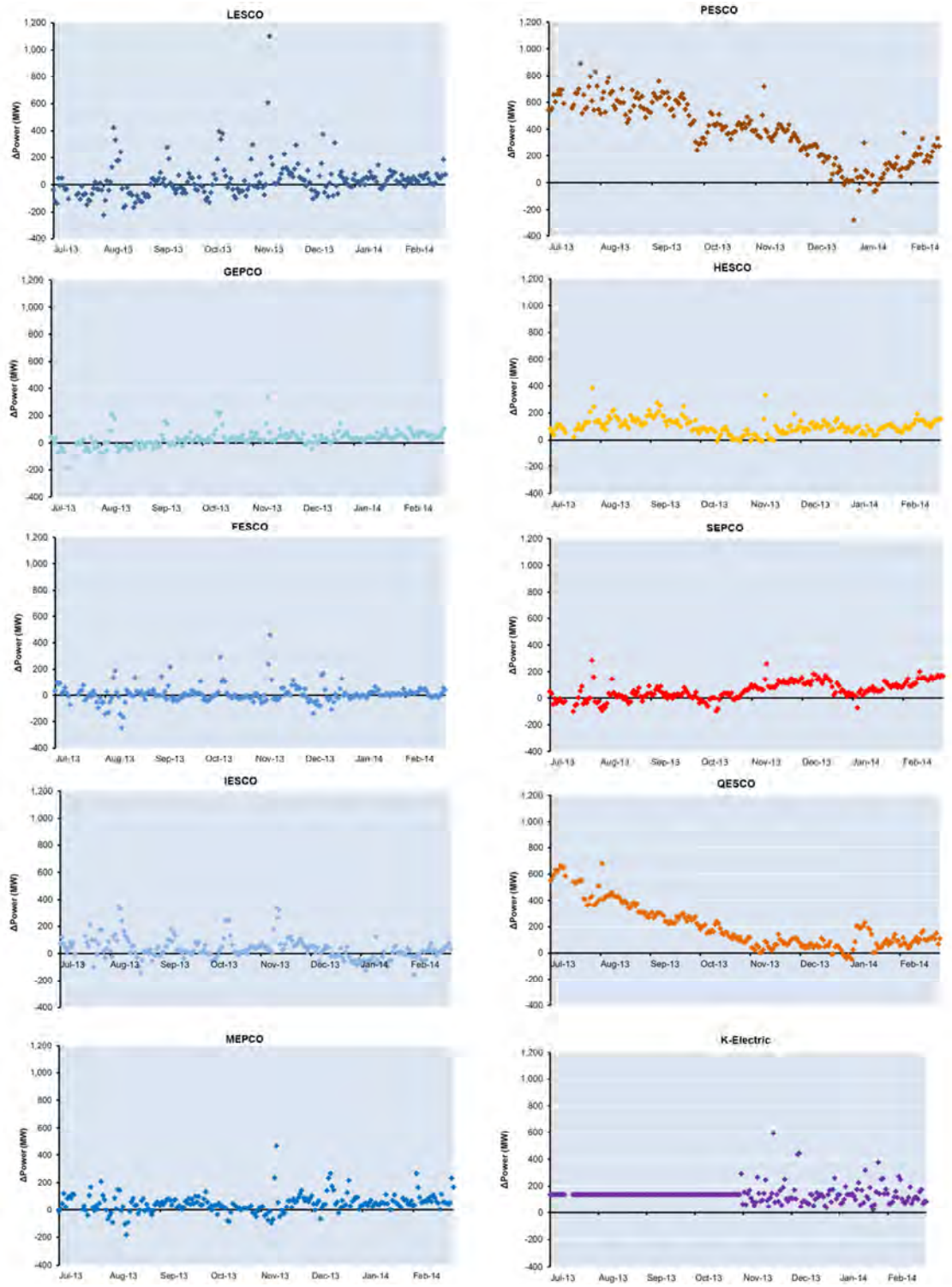
35 The relatively high level of "noise" in the hourly data set evident in

Exhibit 4.10 is partly due to sporadic initial communication issues encountered with some of the LDI equipment, server downtimes, and other system maintenance interruptions, which may have resulted in some spurious datum points being recorded. These operational issues were gradually resolved and the system stabilized during the course of the post-LDI period (as per discussion with PDP, May 6, 2014). In the analysis, only one or two extreme data outliers have been ignored, and averages taken on a daily basis to filter out some of the visible scatter. The overall quantitative assessments, therefore, are not expected to be unduly influenced by such random data noise.

Exhibit 4.10: Hourly Difference Between NPCC Power Allocated and Load Drawn by DISCO from July 9, 2013 to April 30, 2014



It is important to note here that DISCO power allocation, by government directive, is conducted on the basis of their proportional annual load profiles obtained in 2003, the latest year in which there was no load shedding in the country. As the NPCC cannot violate this formulation while reallocating quotas amongst DISCOs based on their actual withdrawals, it resorts to an ingenious method whereby it "inflates" the total available power supply (on which the "actual allocation" is based) by the amount to be reallocated, so that all DISCO allocations are similarly raised, and the Group A DISCOs are not seen, on paper, to be provided with more than their "allotted" shares (while the Group B DISCOs are shown to be voluntarily under-drawing their respective quotas). Therefore, to estimate the amount of power actually supplied to the DISCOs, the NPCC available power pool figures (which are found to exceed total DISCO-drawn power in 72% of the hourly data set analyzed for the period November 1, 2013 to February 28, 2014) are adjusted downwards by this "allocation inflation" factor to arrive at the "adjusted allocations." The overall average total actual allocation across all DISCOs (and K-Electric[36]) was found to exceed the average loss-adjusted generation by 427.1 MW over the stated period. In order to correct for this inflationary factor, hourly NPCC DISCO-wise allocation figures were recalibrated by the amount stated in the "adjustment" column[37] of **Table 2** in the accompanying spreadsheet (**Appendix B.2:** Inter-DISCO Reallocation Computation) and shown in **Error! Not a valid bookmark self-reference.** (except for TESCO,[38] where LDI was not operational during the study period).

[36] In the presence of a large number of blank values in the K-Electric data set, average figures for the available load demand, NPCC allocation and load drawn were used instead. It is important to note that while K-Electric is outside the scope of the LDI project, values pertaining to NPCC allocation and load drawn by all utilities connected to the NTDC grid are required to develop aggregated national level figures used in the analysis.

[37] The adjustment amount for each hour is computed by dividing the hourly DISCO allocation amount with the aggregated NPCC allocation value for all DISCOs and multiplying this ratio with the corresponding difference between loss-adjusted generation and aggregated NPCC load allocation. When summed with NPCC allocation figures for the DISCOs, values for the adjusted DISCO allocation figures can be derived.

[38] For the purpose of quantifying the financial impact, the limited number of values available in the dataset for TESCO are treated as part of PESCO. Additionally, two negative outliers for load drawn by QESCO are excluded from the computation.

Exhibit 4.11: DISCOs Power Allocation by NPCC (November 1, 2013-February 28, 2014)

DISCO	Average Hourly NPCC Allocation I	Average Adjustment to Match Hourly Generation II	Adjusted Hourly DISCO Allocation III	Average Actual Hourly Load Drawn IV	Difference Between Adjusted NPCC Allocation and DISCO Load Drawn III – IV
	MW	MW	MW	MW	MW
Group A					
IESCO	822.8	–35.1	787.7	804.8	**–17.1**
GEPCO	695.9	–29.4	666.5	649.2	**17.2**
LESCO	1,708.7	–72.9	1,635.9	1,648.3	**–12.5**
FESCO	986.2	–42.0	944.2	975.4	**–31.2**
MEPCO	1,232	–52.3	1,179.7	1,172.1	**7.5**
Group B					
SEPCO	449.1	–19.2	429.8	349.4	**80.4**
HESCO	533.8	–22.7	511.1	447.4	**63.7**
QESCO	488.6	–20.9	467.7	412.6	**55.1**
PESCO	1,306	–56.5	1,249.7	1,092.6	**157.1**
PESCO	1,306	–56.5	1,249.7	1,092.6	**157.1**

Information in **It is** important to note here that DISCO power allocation, by government directive, is conducted on the basis of their proportional annual load profiles obtained in 2003, the latest year in which there was no load shedding in the country. As the NPCC cannot violate this formulation while reallocating quotas amongst DISCOs based on their actual withdrawals, it resorts to an ingenious method whereby it "inflates" the total available power supply (on which the "actual allocation" is based) by the amount to be reallocated, so that all DISCO allocations are similarly raised, and the Group A DISCOs are not seen, on paper, to be provided with more than their "allotted" shares (while the Group B DISCOs are shown to be voluntarily under-drawing their respective quotas). Therefore, to estimate the amount of power actually supplied to the DISCOs, the NPCC available power pool figures (which are found to exceed total DISCO-drawn power in 72% of the hourly data set analyzed for the period November 1, 2013 to February 28, 2014) are adjusted downwards by this "allocation inflation" factor to arrive at the "adjusted allocations." The overall average total actual allocation across all DISCOs (and K-Electric) was found to exceed the average loss-adjusted generation by 427.1 MW over the stated period. In

order to correct for this inflationary factor, hourly NPCC DISCO-wise allocation figures were recalibrated by the amount stated in the “adjustment” column of **Table 2** in the accompanying spreadsheet (**Appendix B.2:** Inter-DISCO Reallocation Computation) and shown in **Error! Not a valid bookmark self-reference.** (except for TESCO, where LDI was not operational during the study period).

Exhibit 4.11 indicates that the Group A DISCOs, on average, exceed their adjusted allocated amount from the national power pool, while Group B DISCOs, on average, under-draw from their respective allocated power quotas. The aggregated value of Group B under-drawn power from the NPCC allocated pool corresponds to an hourly average value of 356.3 MW. Over the stated period (November 1, 2013 to February 28, 2014), this translates into 1,024 GWh of energy available for reallocation to Group A DISCOs from the combined Group B quota over the four months.

To calculate the revenue impact of these inter-DISCO power reallocation, the energy transfer is multiplied by the average tariff differential between Group A and Group B DISCOs of Rs 2.06/kWh, which arises from different customer profiles across the DISCOs (see **Table 2** in the accompanying spreadsheet, **Appendix B.2:** Inter-DISCO Reallocation Computation). This additional revenue on account of reallocated power comes to Rs 2.11 billion ($20.8 million) for four months, or Rs 6.32 billion ($62.3 million) when extrapolated to the entire year.

Exhibit 4.12: Six Month Sales Revenue Billed by DISCOs for Pre- and Post-LDI Periods

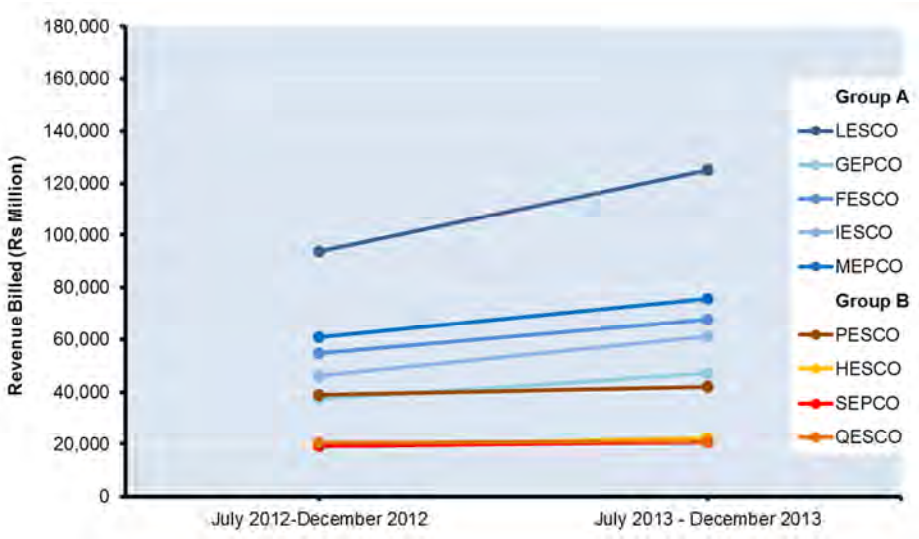


Exhibit 4.13: Year-on-Year Change in Revenue Billed by DISCOs in FY 2010, FY 2011 and FY 2013

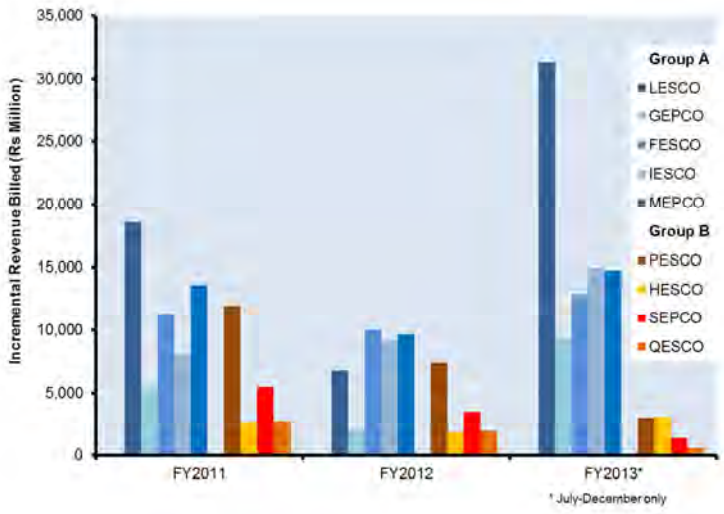


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Exhibit 4.11 indicates that the Group A DISCOs, on average, exceed their adjusted allocated amount from the national power pool, while Group B DISCOs, on average, under-draw from their respective allocated power quotas. The aggregated value of Group B under-drawn power from the NPCC allocated pool corresponds to an hourly average value of 356.3 MW. Over the stated period (November 1, 2013 to February 28, 2014), this translates into 1,024 GWh of energy available for reallocation to Group A DISCOs from the combined Group B quota over the four months.

To calculate the revenue impact of these inter-DISCO power reallocation, the energy transfer is multiplied by the average tariff differential between Group A and Group B DISCOs of Rs 2.06/kWh, which arises from different customer profiles across the DISCOs (see **Table 2** in the accompanying spreadsheet, **Appendix B.2:** Inter-DISCO Reallocation Computation). This additional revenue on account of reallocated power comes to Rs 2.11 billion ($20.8 million) for four months, or Rs 6.32 billion ($62.3 million) when extrapolated to the entire year.

Exhibit 4.12 plots six-monthly DISCO sales revenues billed for the pre- and post-LDI periods, which clearly shows a greater increase in Group A sales compared to those for Group B DISCOs, corroborating the preceding analyses of additional transfers to the former from the latter, in the absence of a significant increase in overall power generation capacity.

Exhibit 4.13 compares the actual total electricity sales growth for both groups of DISCOs over period FY 2010 to FY 2013 in terms of year-on-year incremental change in their billable revenues. At the time of preparation of this report, information for FY 2013 (post-LDI period) was only available for the first six months. Nevertheless, it can be seen that there is a consistent improvement in total DISCO sales revenues during 2010-2013 for all DISCOs, although it is generally higher for Group A DISCOs compared to Group B DISCOs. However, the sales growth for the six-month post-LDI period shown (July-December, 2013) shows a marked jump over previous years, with Group A revenues increasing more than for each of the entire previous two years. The largest increase has been in the case of LESCO, which has seen almost a ten-fold year-on-year increase in incremental revenue in the post-LDI period over the previous year. Even if the net additional power supply available in the LDI period (estimated in **Section 3.3.2** to average 643 MW) is factored out, it is clear that Group A sales revenues have increased significantly since the LDI came into operation, while those of Group B DISCOs have seen far less change. This corroborates the analysis that there has been a transfer of additional quota from Group B to Group A DISCOs in the post-LDI period, leading to a net increase in overall DISCO sales revenue. Thus,

Exhibit 4.13 shows that in the six-month post-LDI period of July 1-December 31, 2013, total DISCO revenues increased by Rs 91.4 billion ($900.5 million) to Rs 491 billion ($4.83 billion) on account of all the revenue determinant factors enumerated earlier in **Section 4.3.1**, of which Rs 3.16 billion ($31.2 million), or 3.5%, is on account of inter-DISCO transfer of power allocations. Assuming that this transfer is largely a result of better monitoring of DISCO loads and matching of dispatch with real-time network demand, it can be surmised that a major portion of this benefit can be attributed to the LDI facility and give NTDC operators' access to such timely information.

4.3.1.2. OVERALL FINANCIAL PERFORMANCE OF DISCOS

It was observed that the overall energy supplied to DISCOs increased by 7.3% in the post-LDI period, while DISCO energy sales to end-consumers increased by 7.6%, compared to the pre-LDI period. The financial impact of the LDI project on utility billing and revenue collection was assessed for the six-month pre- and post-LDI project periods of July 2012 to December 2012 and July 2013 to December 2013, as published data exists only on a financial year basis.[39]

With the help of the LDI-provided load profile data accumulated by feeder and matched with billing information, DISCOs are now able to implement AT&C loss-based load shedding[40] (currently practiced by K-Electric), thereby improving their revenue collection indices both by reducing unsold power earlier consumed by system losses and by redirecting power to higher tariff paying customers. Since the latter includes the productive sectors of the economy, such as industry and commercial businesses, there is also an indirect positive impact of such AT&C-based system management practices on the national economy.

In the current analysis of pre- and post-LDI utility financial records, a comparison of distribution-related losses[41] presented in **Exhibit 4.14** shows an overall reduction of only 0.2% in electricity losses for all DISCOs in the six month post-LDI period over the same pre-LDI period in the previous year. However, although the LDI system has been installed in QESCO, their PDC center is not yet functional, while LDI equipment is presently being installed at TESCO and is also not operational. The impact of LDI in these DISCOs, therefore, cannot be gauged. PESCO, on the other hand, was already engaged in implementing AT&C-based load shedding for at least a couple of years prior to LDI installation, and therefore any LDI-enabled AT&C-based load management comparison would be irrelevant or negligible. It can be seen in the exhibit that,

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[39] WAPDA [2011-13].

[40] PESCO is now officially implementing AT&C-based load shedding practices. The other DISCOs also undertake this to different extents, but are legally constrained in this respect by a High Court ruling calling for 'equitable' dispatch to all consumers.

[41] Only comparative losses in feeders of 11 kV and below were considered, as the LDI project does not cover 132 kV transmission lines and grid station operations.

excluding these three DISCOs (QESCO, PESCO, and TESCO), the remaining DISCOs showed an overall improvement of 0.5% in technical losses, resulting in an additional total billed units of 152 million kWh, corresponding to Rs 2,011 million in additional receivables for the six-month post-LDI period, or roughly Rs 4 billion a year. While this entire amount cannot be attributed directly as an outcome of the LDI project (as the DISCOs have simultaneously been implementing system-wide infrastructure improvements that are also resulting in reduced technical losses), it can be assumed that at least a part of the additional revenue generation has been made possible through loss reduction afforded by better LDI-enabled load management and dispatch practices by the seven DISCOs considered.

Exhibit 4.15 shows the actual revenue collection by DISCOs over the same six month pre- and post-LDI periods. Overall, DISCOs showed a drop of Rs 1,104 million in their revenues between the two periods. GEPCO, IESCO, TESCO and MEPCO were collectively responsible for a decrease of Rs 5,420 million, while others showed an improvement of the order of Rs 4,322 million in their revenue collection in the post-LDI period. As in the case of the technical and commercial losses, improvement or decrease in revenue collection at each DISCO cannot be entirely attributed to LDI operations, and the overall losses in some DISCOs may be symptomatic of other significant factors constraining their financial performance.

4.3.2. SERVICE DELIVERY

Higher reliability indices for power DISCOs, better service delivery, and reduction in response and down times due to emergencies, contingencies, maintenance, and fault correction as a result of availability of real-time data on system loads, feeder status, faults, and load shedding are also a direct benefit of the LDI project. These have been discussed in more detail in **Section 5.1** in the context of possible long-term beneficial impacts of LDI on DISCO management and performance factors, but would start accruing immediately as system-wide information flows improve, as witnessed in the case of K-Electric. This would lead to higher levels of customer satisfaction, increased willingness to pay for services (including differentiated and Time of Use (TOU) tariffs) for more reliable supplies, higher levels of consumer cooperation with utility staff and in the reporting of theft and meter tampering in their vicinity, reduced damages to electrical equipment and benefits to the national economy resulting from fewer disruptions and fluctuations in the power supplied to industry, commercial businesses, agriculture, and other productive sectors. At the household and individual level, improved electricity service delivery leads to greater economic and employment opportunities, higher income levels, better access to basic social services, reduction in unproductive labor, and generally improved comfort and leisure.

Exhibit 4.14: Comparison of Technical and Commercial Losses and Revenue Billed by DISCOs for FY 2012 and FY 2013

DISCO	Post-LDI Period (July 2013-December 2013)				Pre-LDI Period (July 2012-December 2012)				Change in Losses	Change in Units Billed	Amount Billed Post-LDI Period (07/2013 - 12/2013)	Average Sale Rate	Change in Billing
	Received	Billed	Loss	Loss	Received	Billed	Loss	Loss					
	Million kWh			%	Million kWh			%	%	Million kWh	Million Rs	Rs/kWh	Million Rs
LESCO	9,763	8,621	1,142	11.7%	8,884	7,803	1,081	12.2%	-0.5%	45.59	125,033	14.50	661
GEPCO	4,063	3,722	341	8.4%	3,689	3,375	314	8.5%	-0.1%	4.31	46,911	12.60	54
FESCO	5,730	5,243	488	8.5%	5,275	4,800	475	9.0%	-0.5%	28.56	67,534	12.88	368
IESCO	4,820	4,536	284	5.9%	4,529	4,238	291	6.4%	-0.5%	25.77	61,044	13.46	347
MEPCO	7,266	6,198	1,068	14.7%	6,411	5,446	965	15.1%	-0.4%	26.18	75,693	12.21	320
PESCO	5,905	3,993	1,912	32.4%	5,650	3,841	1,809	32.0%	0.4%	(21.49)	42,029	10.53	(226)
TESCO	946	770	175	18.5%	944	753	191	20.2%	-1.7%	15.96	9,116	11.83	189
HESCO	2,586	1,965	621	24.0%	2,537	1,913	625	24.6%	-0.6%	15.60	22,136	11.27	176
SEPCO	2,460	1,551	909	36.9%	2,399	1,507	893	37.2%	-0.3%	6.44	20,600	13.28	85
QESCO	2,462	1,918	544	22.1%	2,554	2,133	420	16.5%	5.6%	(138.94)	21,057	10.98	(1,526)
Total	**46,001**	**38,517**	**7,484**	**16.3%**	**42,872**	**35,808**	**7,063**	**16.5%**	**-0.2%**	**94.79**	**491,153**	**12.75**	**448**
Total (w/o TESCO)	45,055	37,746	7,308	16.2%	41,927	35,055	6,872	16.4%	-0.2%	76.23	482,037	12.77	974
Total (w/o PESCO, TESCO & QESCO)	**36,688**	**31,836**	**4,853**	**13.2%**	**33,724**	**29,081**	**4,643**	**13.8%**	**-0.5%**	**198.74**	**418,952**	**13.16**	**2,615**

Exhibit 4.15: Comparison of Revenue Collection by DISCOs for FY 2012 and FY 2013

DISCO	Post-LDI Period (July 2013-December 2013)			Pre-LDI Period (July 2012-December 2012)			Change in Recovery	Change in Revenue
	Amount Billed	Amount Collected	Recovery Rate	Amount Billed	Amount Collected	Recovery Rate		
	Million Rs	Million Rs	%	Million Rs	Million Rs	%	%	Million Rs
LESCO	125,033	119,424	95.5%	93,717	89,026	95.0%	0.5%	620
GEPCO	46,911	44,848	95.6%	37,509	36,941	98.5%	-2.9%	(1,293)
FESCO	67,534	67,026	99.2%	54,631	53,749	98.4%	0.9%	579
IESCO	61,044	53,834	88.2%	46,099	43,562	94.5%	-6.3%	(3,396)
MEPCO	75,693	70,101	92.6%	60,824	56,394	92.7%	-0.1%	(73)
PESCO	42,029	35,355	84.1%	39,013	31,949	81.9%	2.2%	787
TESCO	9,116	509	5.6%	9,139	12,428*	136.0%	-130.4%	(664)
HESCO	22,136	17,439	78.8%	19,072	14,917	78.2%	0.6%	98
SEPCO	20,600	11,261	54.7%	19,215	8,514	44.3%	10.4%	1,166
QESCO	21,057	8,822	41.9%	20,463	6,086	29.7%	12.2%	1,072
TOTAL	**491,153**	**428,618**	**87.3%**	**399,682**	**353,566**	**88.5%**	**-1.2%**	**(1,104)**
Total (w/o TESCO)	482,037	428,109	88.8%	390,543	341,138	87.3%	1.5%	(440)
Total (w/o PESCO, TESCO &QESCO)	**418,952**	**383,932**	**91.6%**	**331,068**	**303,103**	**91.6%**	**0.1%**	**(2,299)**

* Includes payment of federal government subsidy amount.

5. ADDITIONAL FUTURE BENEFITS

5.1. IMPROVED UTILITY MANAGEMENT AND OPERATIONS

The LDI system generates power inflow data at the 11 kV bus bars at grid stations and transmits it at one-minute intervals to the DISCO PDC center in real-time. Similarly, the data on outgoing feeders is transmitted at 15-minute intervals and contains information on total active and reactive power, energy flow, instantaneous power factor, phase sequence, and the last recorded load on the feeder before it tripped or opened for load shedding. This LDI-generated data is displayed on DISCOs' operator and management consoles, as well as being recorded in an electronic database for archiving and subsequent analysis. This comprehensive, disaggregated, up-to-date information greatly facilitates DISCO monitoring of feeder loads, allocation and management of load shedding schedules, and real-time assessment of grid balances and performance, providing operators with precise control on load management as PDC center operators can now directly verify feeder operation on their screens without having to query individual grid station personnel, face delays, or cater for synchronization issues. Prior to the implementation of the LDI, controllers at NPCC and DISCOs had minimal system information at their disposal, relying virtually on a single instantaneous frequency reading to balance the entire grid, communications were handled verbally, and data recorded and reported manually which resulting in long response times and failure to take timely corrective action. As a result, system operators would be forced to make operational decisions virtually "in the blind," resorting to over-compensating dispatch in some instances (at both the DISCO and feeder levels), forcing unnecessary outages at others, loading transformers and transmission lines beyond safe limits—resulting in significant instability in grid frequency and voltages, which routinely damaged the power distribution infrastructure including end-use equipment, and greatly increased the risk of triggering grid collapse. Not a single element of real- or near-real-time information now displayed on DISCO and NPCC screens through the LDI project was previously available to the country's power system managers for exercising proper operational control on the grid, without which its stable and optimal performance was critically undermined and its sustained viability and expansion greatly jeopardized.

It should be pointed out that due to the constant and multi-layered oversight at DISCO management, and operations control levels now possible with real-time monitoring down to the sub-132kV network, the LDI system has virtually eliminated the ability of grid station operators to exercise their individual discretion in changing load shedding schedules to suit influential customers, "sell" load shedding exemptions, or resort to other corrupt or associated practices that previously used to result in disproportionate load shedding for other deserving

utility customers. As load shedding has now become more regular and predictable with near elimination of unscheduled outages, public perceptions, levels of service satisfaction, and responsiveness and cooperation level with DISCO staff are expected to improve, as already witnessed in the case of the private utility, K-Electric, where such improvements had been independently implemented earlier. DISCOs will also be able to monitor the impacts of load shedding by corroborating LDI data with their commercial data and can design more responsive load shedding policies and schedules

Additionally, some utility-owned loads connected directly to the 11 kV networks which were previously not separately monitored are now being much better regulated, reducing such "unaccounted for" auxiliary diversions and losses. With the high-resolution, cumulative system-wide data history at their disposal, DISCOs will be able to better refine their load shedding plans in the light of anticipated trends and lessons learned.

The LDI-generated data can readily provide grid station and feeder load profiles and growth trends and can help DISCOs project their system augmentation and expansion plans in a more timely and optimal manner to ensure the proper planning and development of infrastructure and deployment of resources. DISCOs can now also undertake discrete programs for transformer and line augmentation by using the LDI database to estimate loads, profiles, and replacement or upgrade needs in advance, resulting in more cost effective investment decisions based on consumer patterns and revenues expectations.

The LDI dataset also enables much better system performance monitoring, and facilitates the development and implementation of KPIs in areas such as outage and tampering reporting, fault rectification, complaint response, AT&C loss reduction, cash recovery index (CRI), service quality (e.g., Customer Average Interruption Duration Index (CAIDI), power quality), BEI, and customer satisfaction. In the short-term, the LDI system (with further modifications) can become instrumental in monitoring and evaluation of utility service quality standards as the system, by default, records and transmits a constant data stream on all feeder outages, outage durations, voltage and power factor profiles, and specific event reports and alarms, which are key parameters required for the assessment of power quality, system performance and service delivery. The DISCOs, in consultation with NEPRA, could expand the LDI scope to include the automated generation of periodic power quality assessment reports for this purpose.

International best practices of utility management are based on prudent and fast decision-making, strict compliance with standard operating procedures at all levels, and secure, accurate and discrete information sharing, through automated ICT systems that require minimal human intervention, between all levels of management and operations. LDI provides DISCOs with the means for such information management and communication which was previously severely lacking, thereby enabling them to bring other utility functions at par with best practices.

The LDI system can be integrated with advanced metering infrastructure (AMI) systems on the DISCO grids for reducing system losses, improving revenue recovery and discrete load management at the consumer end as part of 'smart metering' initiatives. The existing of feeder load profiles can facilitate the implementation of pilot schemes in this regards, where the effectiveness of various AMI elements can be readily tested on a pilot scale to study their impacts using LDI monitored pre- and post-implementation comparisons. LDI can thus serve as a first step towards the implementation of smart grids in DISCOs, as this requires the installation of smart meters at each stage of power transmission and transformation, including at the outgoing control panel of each distribution feeder. DISCOs will also need to install smart meters at the distribution transformers and consumer premises for monitoring and control of commercial losses.

In the short-term, DISCOs can opt for differentiated load shedding on feeders based on their respective AT&C Losses to penalize poorly performing regions and improve the overall revenue recovery and financial viability of the distribution utilities, a pressing need in the context of the overall economics of Pakistan's power sector. K-Electric is using this approach in its service territory, and has achieved an estimated reduction of 2.1% in commercial losses over 28% total T&D losses.

LDI facilities can greatly enhance the efficiency and performance of the network, as potential equipment faults can be more precisely identified, preempted and isolated, and DISCO staff can now focus on fixing the network rather than locating problems. In the event of a natural calamity, for instance, DISCO staff can use the real-time LDI-provided information to locate problem areas and prioritize restoration of network faults, or isolate and repair damaged portions, which should result in reduction in outage times and lost revenues, besides reducing damage and aiding rehabilitation of affected areas.

5.2. IMPROVED POLICY FORMULATION

With differentiated load shedding based on AT&C losses enabled by LDI system monitoring, utility revenues are expected to increase, which should result in a reduction in the current chronic DISCO revenue deficits and consequently reduce the debilitating circular debt plaguing Pakistan's power sector, which necessitates a huge indirect subsidy to be annually provided by the government. However, the implementation of AT&C-based load shedding requires an appropriate policy directive by the government in this regard. The Punjab High Court has directed DISCOs to implement uniform load shedding schedules and avoid consumer discrimination; a policy directive will help build public pressure to identify and prosecute electricity theft and corrupt practices as the only alternative to preventing discriminatory load shedding. The recent experience of K-Electric can be used as a guide to develop and implement effective AT&C-based load shedding, as and when it becomes feasible to do so.

Typical consumer load profiles and peak coincidence factors are critical inputs to cost-of-service calculations for various consumer categories and for appropriate tariff design for each consumer category. Accurate consumption profiles can be drawn for different consumer categories by analyzing LDI data, and tariff designs can be evolved that are aligned with actual usage characteristics of the target consumer groups to determine commercially sustainable retail electricity tariffs in the long-term.

Despite significant sector improvements and attractive policy incentives for private sector participation in power sector management and operations in order to increase efficiency and performance, the government has not been able to induce risk-shy investors to overcome their suspicions about the credit-worthiness and growth prospects of public sector entities in the country. With the full implementation of LDI, smart grids and the introduction of automatic monitoring and control systems, these commercial risks can be better identified and mitigated through rapid and accurate flows of more credible operational information. The LDI mechanism can help in identifying system strengths and weaknesses, providing prospective management to more easily formulate responsive solutions and evaluate future prospects. This may result in a better assessment of DISCO asset and business value, and may result in improved investor interest and confidence in the DISCO privatization process, a long running priority objective of the GOP.

As part of its wide ranging power sector reform program, the GOP established the CPPA , currently affiliated with the NTDC, to fulfill its singular function of a truly autonomous “single buyer” of electricity from grid-connected generators that can enforce contract and transactions according to regulator-defined market rules and ensure proper invoicing and payments. For this purpose, the CPPA has installed its own SMS at each of the NTDC/DISCO delivery points for accurate billing of the transfer price for the power purchased by the DISCOs. The use of the CPPA’s SMS, along with LDI meters at the 11 kV bus bar of the 132 kV grid stations, can help accurately measure 132 kV transmission and transformation losses in the distribution system. This will result in an accurate bifurcation of T&D losses in the DISCOs, and can help DISCOs in devising strategies to reduce these losses through targeted measures in each domain.

Additionally, if the government allows DISCOs full freedom in dispatching electricity on the basis of AT&C losses, the CPPA can be entrusted to monitor power distribution by DISCOs as a means of ensuring its revenue receipts from them. The LDI system, in such a case, can provide a ready means of monitoring and controlling power distribution on an optimum basis for reducing AT&C losses.

5.3. ENHANCED INFORMATION ACCESS

As mentioned previously, LDI-based system monitoring provides a greatly improved ability for DISCOs to design, pilot and assess new and innovative service improvement methods (e.g., smart metering, TOU tariffs, etc.) based on availability of actual, real-time customer-based usage and performance monitoring data to utilities. End users of electricity could also be included in the beneficiaries of such enhanced information access, which would provide several additional benefits. For example, the elimination of chronic forced load shedding and advance notification of planned load shedding by feeder or locality through readily accessible, on-demand public communication channels (mobile SMS, website, etc.) can allow consumers to better adjust to power shortages, reduce inconvenience and damages, enhance customer-utility relations, and improve consumers' willingness to pay for service and cooperate with utility staff. For instance, institutionalization of better customer information systems and predictability of outage schedules not only enabled K-Electric to attain such benefits, but also vastly increased the reporting of illegal connections, meter tampering, and other disruptive behavior in their neighborhoods by customers to further help improve service delivery once they were convinced that the utility was providing them with accurate and useful information of its own.

Improved performance in all economic sectors is also made possible through more reliable and predictable power supply, as discussed in **Section 4.1**. Provision of relevant operational information, at a disaggregated local level, can greatly enhance the capacity of industry, commercial businesses, agri-services, and individuals to better plan their productive activities, work schedules, and provide alternative solutions, that can help reduce overall economic loss, minimize disruptions, and prevent costly and inflationary outcomes that would otherwise result from recurrent power shortages.

6. CONCLUSIONS

6.1. BACKGROUND

- In recent years, Pakistan has been struggling with severe power shortages—of the order of 5,000 MW in the summer—leading to extensive electricity outages, or "load shedding", that have not only adversely affected its economy, with industrial production and GDP growth significantly reduced, but also disrupted essential social services and greatly inconvenienced the population at large, leading to frequent violent street protests. By one authoritative estimate, the cost of power outages to the nation's economy amounted to Rs 1.4 trillion ($14.3 billion), or 7% of the national GDP, in 2011-12.
- The GOP, therefore, has placed resolving the energy crises at the top of its economic agenda. It is keen to address shortfalls and constraints in all segments of the power sector, from generation to transmission and distribution, as well as to resolve the crippling circular debt stemming various power sector entities and discouraging new investments and expansion. PDP is designed to assist the government in achieving this objective by focusing on improving the performance and capacity of the electricity distribution system operated by the ten state-owned DISCOs.

6.2. THE LDI INTERVENTION

- The LDI project, currently being implemented under PDP, is primarily designed to monitor network loads and power flows up to the interface of the electricity distribution system, operated by various DISCOs, with the national power transmission grid operated by the NTDC. LDI hardware, including AMR meters, communication links, computer servers, and information display panels, along with custom-designed MDM software and databases, provide detailed network operational performance and quality parameters on a near-real-time basis to grid operators at the DISCO headquarters and NTDC control centers.
- Prior to the project's commissioning, the national power system was being operated virtually "in the blind", with only a frequency meter to alert operators of general grid imbalances and with no insight into specific DISCO loads and power withdrawals from the national generation pool or into overloaded or malfunctioning feeders and transformers, and all communications and instructions conveyed manually—leading to frequent over- or under-compensation, excessive forced outages, poor power quality, delayed and insufficient reporting, and slow response and remediation times.
- The LDI-provided information represents a quantum jump in terms of data available to network operators for managing the national and regional electricity transmission and

distribution system, providing constantly updated information down to the individual feeder level on system demand, loads, dispatch, consumption, and quality attributes. With the advent of the wealth of accurate, high resolution network data provided by LDI and recorded in electronic databases for real-time operational control as well as for subsequent analysis, power dispatch and distribution functions can now be greatly improved, unnecessary load shedding decreased, power quality and service delivery enhanced, DISCO revenues and profitability increased, and national economic losses resulting from power interruptions reduced, contributing to improving the financial health of Pakistan's power sector, enhancing economic growth prospects, and leading to a better-informed planning and investment process in support of the government's overall power sector reform objectives.

- The original LDI project cost of Rs 309.8 million was subsequently increased to Rs 374.7 million as the scope of work was expanded to include the newly-created tenth DISCO (TESCO) as well as additional features to the project. This study has estimated direct and indirect financial and economic gains resulting from the LDI project that greatly exceed its cost, in addition to identifying a variety of immediate and longer term qualitative benefits that further enhance its overall value and importance both for the power sector as well as Pakistan's economy as a whole.
- The project has been accepted by the NTDC, DISCOs and other key stakeholders in the power sector as an essential element for improving grid management and the supply of electricity to end consumers in Pakistan. It has already demonstrated its ability to help reduce forced or unscheduled load shedding in the country to a great extent and optimize the utilization of existing power generation capacity, a vital step in helping address Pakistan's chronic electricity shortage and reducing its attendant social and economic costs.

6.3. LDI IMPACT ASSESSMENT

- The report assesses the impact of the LDI project based on a comparison of actual grid performance data since its commissioning in July 2013 to February 2014 with the corresponding period a year earlier (July 2012-February 2013). These impacts have been evaluated at the national, power sector, and utility levels, and quantified wherever possible, given data constraints. Additional potential benefits have also been discussed where LDI-enabled decisions and actions could result in more optimized policy and management practices aimed at expediting the sustained and efficient development of the country's power sector.

6.3.1. POWER AVAILABILITY AND DISPATCH

- In Pakistan, the national grid has reportedly been operating in recent years with zero or negligible operational reserve margins. Poor grid frequency control and significant

forced load shedding prevalent in the pre-LDI period corroborate the absence or, at minimum, the inadequacy of stabilizing spinning reserves in a severely supply-constrained national grid. However, direct documentation of existing operational reserves could not be obtained from the NTDC to enable a conclusive determination in this regard.

- In the post-LDI period, an additional 643 MW of power supply was assessed to have been made available to the DISCOs by NTDC. However, this is attributed to the commissioning of 332 MW of new hydropower and wind power generation capacity, as well as greater availability of existing plants (due to improved fuel supply, payment of past dues, and upgrades) in the interim. While the LDI project is not expected to affect the available generation pool, it could conceivably help optimize spinning reserves through better insight into system load requirements, enabling more accurate estimation of the minimum requirements. However, in the absence of verifiable information on NTDC's operational reserves, the impact of the LDI on releasing excess reserve capacity could not be determined.
- In the future, however, if sufficient generation capacity is developed in Pakistan that can adequately meet demand and routine load shedding is finally eliminated, the LDI project can be expected to help optimize the operational reserve requirements resulting in more productive use of available generation capacity, including a greater supply to DISCO customers as an outcome of such reserve trimming.
- Nevertheless, in terms of overall power dispatch by NTDC, LDI has enabled better management of the allocation of supply quotas to the DISCOs, resulting in the projected transfer of about 1,024 GWh of energy from DISCOs under-drawing their quotas to those facing higher loads in FY 2013. This would not only help improve power supply for more productive uses (e.g., industrial customers), but would also result in overall higher DISCO revenues due to the tariff differentials involved, as discussed later in this report.
- In addition to the separate SMS metering of large generators implemented by NTDC, LDI also meters all SPPs connected to the grid, enabling the NTDC to now have a more comprehensive picture of all power injected into the grid and available for dispatch to the DISCOs at any given time.

6.3.2. POWER QUALITY

- Utility line frequency (or mains frequency) is the sole indicator of the overall health of the power grid system, with other power quality parameters being a function of local supply and end-use conditions. Deviations in power frequency from regulator-prescribed standards can adversely affect all kinds of end-use equipment, from elements of the power infrastructure itself (e.g., transformers) to industrial machinery as well as commercial, municipal and domestic devices. This can lead to disruptions in the power supply itself, equipment malfunction and shutdown, and even permanent

damage to sophisticated and expensive machinery. The financial and economic consequences of poor power quality can therefore be significant.

- Based on a random pre- and post-LDI frequency comparison carried out in this study, there appears to be a marked improvement in power quality in terms of post-LDI electricity supply being constrained to a well-defined frequency band which is both more stable and narrower compared to the measurements taken during the pre-LDI period. Whereas in the pre-LDI case, frequency deviations from the target grid frequency of 50 Hz were greater, routinely exceeding the NEPRA-specified nominal (Frequency Response Mode) range while also violating the Tolerance Frequency and Contingency Frequency Bands allowed for extraordinary situations. In the post-LDI phase, the Tolerance and Contingency Frequency Bands are observed to be respected, although the lower bound of the Frequency Sensitive Mode is still routinely exceeded, symptomatic of a supply-constrained grid. The overall standard deviation in recorded frequency over a corresponding 24-hour pre- and post-LDI sample period showed an almost 26% reduction after the implementation of LDI.
- These observations are indicative of a positive impact of LDI on system frequency, and therefore, on the maintenance of system-wide power quality. Not only would this help reduce electricity supply disruptions and damage to the power infrastructure (particularly transformers, where frequency-induced damage is cumulative and irreversible) and improve the longevity of system components, but it would also reduce the inconvenience and material losses suffered by consumers—and the economy at large—as a result of variable power quality.

6.3.3. LOAD SHEDDING

- Power outages, or “load shedding”, are resorted to by DISCOs under two different scenarios: “scheduled” load shedding, which is planned and announced in advance due to an expected shortfall in available power supply (i.e., generation capacity) and expected overall system demand, and “unscheduled” load shedding mainly owing to unexpected surges in loads or unforeseen generation outages, T&D constraints, faults, etc.
- A detailed analysis of supply and demand balances, power allocation and load shedding patterns at an aggregated level for all DISCOs shows that unscheduled load shedding in the post-LDI period appears to have been consistently reduced when compared with the same period in the previous year. The decline of unscheduled load shedding from a previous monthly average of 9% of total load shedding to less than 2% is coincident with the commissioning of the LDI project initially at nine DISCOs in July 2013, and remains consistently low thereafter.
- This translates to a shift of about 200 MW, corresponding to 1,805 GWh in energy terms over a year, from unscheduled to scheduled load shedding, as the total amount of load shedding in the country remained unaffected, which implies that there was no significant net addition to overall available power supply (with net additions of 643 MW

calculated for the post-LDI period apparently catering to normal year-on-year demand growth).

6.3.4. ECONOMIC IMPACTS

- This study utilized recent comprehensive assessments for the impact of power outages on Pakistan's economy to monetize any primary benefits accruing from the LDI project in terms of changes to load shedding patterns. The analysis did not include several possible secondary economic impacts, such as those due to power quality improvements, as these cannot be readily quantified.
- Since it was observed that total load shedding in the country remained unchanged in the post-LDI period, the analysis focused on the differential between the impacts of unscheduled vs. scheduled load shedding, and calculated the net impact of a reduction in unscheduled load shedding attributed to the onset of the LDI project.
- Of the total economic impact of load shedding of Rs 14.2 trillion ($14.3 billion) previously evaluated for FY 2012, the LDI project has been estimated to reduce annual losses by Rs 18.3 billion ($180 million), or 1.3%, purely on account of reducing unscheduled load shedding to negligible levels. These savings compare favorably with the LDI implementation cost of $3.7 million.
- The impact of LDI is proportionately highest for the industrial sector, with a loss reduction of Rs 15.9 billion ($156.5 million), or 5.1% of total sector outage costs, followed by the commercial sector at Rs 1.5 billion ($14.7 million) and the residential sector at Rs 709 million ($7 million), or a 0.3% reduction in outage losses in both cases. The impact of a reduction in unscheduled load shedding is not expected to impact the agricultural sector appreciably.

6.3.5. SOCIAL IMPACTS

- There are a variety of social impacts of disruptions in power supply, as these lead to a loss in individual employment and incomes, degrade essential services such as healthcare and education, reduce opportunities for leisure, and adversely impact general quality of life and living standards. However, these disparate social impacts can be subjective, highly context sensitive and interrelated, with many having long-term implications, which makes their quantification extremely difficult.
- Generally, access to reliable, affordable electricity has been universally found to have a strong correlation with overall social well-being as measured, for instance, by internationally accepted indicators such as the HDI. It can be stated, therefore, that any improvement in Pakistan's power supply situation would have a positive social impact on its population, both in terms of additional supplies provided (which directly help elevate HDI values) as well as by a reduction in unscheduled load shedding (which by its very nature, is more disruptive and harmful than scheduled load shedding as consumers can plan and adjust better against the latter).

- Given the lack of verifiable information on existing NTDC operational reserves, it is not possible to estimate any additional power supply made available to the national grid purely on account of LDI implementation. If such an amount can be verified, it would be possible to deduce the resulting improvement in the HDI value for the country as a whole from the additional power supplied to consumers. Although a possible △HDI would be small, given its extreme sensitivity to per capita electricity use changes for developing countries such as Pakistan, this relationship would nevertheless be significant and important to bear in mind, especially in the longer term as LDI helps facilitates overall improvements in the country's power sector.
- By helping reduce unscheduled load shedding, the LDI is also expected to result in immediate social betterment of DISCO customers, particularly the predominant proportion employed in small-scale enterprises, cottage industry, retail services, as well as residential consumers.

6.3.6. UTILITY PERFORMANCE

- The immediate qualitative impacts of the LDI project on DISCO operations include much greater visibility into network performance and asset management, leading to better dispatch practices, reduced overloading and damage to distribution infrastructure, improved detection of theft and corrupt practices, and the resultant reduction in both technical and non-technical losses. This is expected to result in not only service improvement and better fault preemption and correction, but also monetary gains for the DISCOs in terms of higher sales, reduced downtimes and lower equipment maintenance or replacement costs.
- Due to the constant and multi-layered oversight at DISCO management, and operations control levels now possible due to real-time monitoring down to the sub-132kV network, the LDI system has virtually eliminated the ability of grid station operators to exercise their individual discretion in "selling" load shedding exemptions or selectively implementing excessive feeder outages. Additionally, some utility-owned loads connected directly to the 11 kV network which were previously not separately monitored are now be much better regulated, reducing such "unaccounted for" auxiliary diversions and losses.
- LDI facilities can greatly enhance the efficiency and performance of the network, as potential equipment faults can be more precisely identified, preempted and isolated, and DISCO staff can now focus on fixing the network rather locating problems.
- Excluding QESCO, PESCO, and TESCO, the remaining DISCOs showed an overall improvement of 0.5% in technical losses, resulting in an additional 152 million kWh of total billed units, corresponding to Rs 2,011 million in additional receivables for the six-month post-LDI period, or roughly Rs 4 billion a year. At least a part of this additional revenue generation has been made possible through loss reduction afforded by better LDI-enabled load management and dispatch practices.

- Armed with feeder-specific LDI data, DISCOs can now institute effective economic dispatch of power based on AT&C losses, which can lead to significantly increased utility billing and revenues (as demonstrated by the private utility, K-Electric). This is expected to improve the overall operational and financial performance of the DISCOs, and enable them to improve service delivery further and better plan their future expansion.
- Based on their respective T&D losses, bill recovery rates and utilization of allocated power, the DISCOs can be broadly grouped into two categories: Group A, or the better performing DISCOs (i.e., LESCO, IESCO, FESCO, GEPCO and MEPCO), typically having lower T&D losses, higher collection rates and higher power quota utilization rates (with a likelihood of excessive demand, demonstrated by frequent overdrawing of supply from the national power pool), and Group B, or underperforming DISCOs (i.e., QESCO, PESCO, SEPCO, HESCO and TESCO), with relatively high T&D system losses on account of pilferage and poor infrastructure, poor bill recovery rates and low average consumer ability to pay, leading to self-imposed load shedding necessitated by these constraints which generally results in under-drawing of power from their NPCC-allocated quotas.
- The instantaneous access to key power sector information at the DISCO and national levels afforded by LDI have allowed the NPCC to optimize power supply allocations to the DISCOs. Analysis indicates that Group B DISCOs underutilized their hourly power allocation quota by a total of approximately 356 MW during the post-LDI months of November 1, 2013 to February 28, 2014 for which such data are available, for a four-month total of 1,024 GWh. This energy, reallocated to Group A DISCOs, with their average retail tariffs being comparatively higher by Rs 2.06/kWh, results in a total annual revenue gain for these DISCOs of Rs 6.32 billion ($62.3 million) when extrapolated to the entire post-LDI year.
- This additional billable amount represents a 3.5% increase in year-on-year incremental revenue for Group A DISCOs. Since Group B DISCOs also recorded positive but nominal revenue growth during this period, it may be surmised that the LDI helped improve overall DISCO billing by up to this amount, thereby helping improve the overall financial health of the distribution sector.
- A positive impact on the DISCOs' financial situation would help release much-needed funds for system infrastructure and service improvements which would otherwise not be undertaken, lead to performance deterioration and greater losses, or otherwise have to be carried out through federal government financing. Diversion of uneconomical power dispatch in high-loss Group B DISCOs to more productive, higher paying customers in Group A DISCOs also directly helps reduce the TDS payable by the government to the former on account of their poor recovery rates. Both factors would contribute to a reduction in the power sector circular debt, which partly results from delinquent government payment of such dues.
- Actual revenue collection by the DISCOs exhibited a cumulative decline of Rs 1.1 billion over the six-month post-LDI period due to a variety of factors unrelated to LDI operations. It can therefore be stated that in the absence of LDI, the revenue could

have been higher by as much as Rs 3.16 billion, or almost four times the recorded amount.

6.3.7. LONGER TERM BENEFITS

- In the short- to medium-term, the LDI intervention will allow DISCOs accustomed to utilizing system-wide LDI-generated data to analyze grid load patterns, feeder performance, consumer load profiles, and undertake better dispatch planning and service and revenue optimization schemes. The revised phase of the LDI project is already helping DISCOs develop more comprehensive LDI-based reporting and analysis tools. This is expected to improve service quality and efficiency, raise consumer satisfaction levels, and increase their willingness to pay for reliable, uninterrupted power supplies, as well as help utility management and staff in daily system maintenance, bill collection, and theft reduction.
- As an example, K-Electric has employed improved load management practices enabled by AMR installations which helped reduce forced load shedding and the implementation of AT&C-based dispatch practices, along with several other related customer service improvements. These have resulted in an improvement of the company's BEI— which has a positive association with customer willingness-to-pay— from a level of 0.78 in October 2009 to 3.2 in December 2011. These, amongst a variety of other measures, enabled K-Electric to return the company to profitability for the first time in 2012 after a period of 17 years, reduce system losses considerably and thereby eliminate load shedding completely for large numbers of its paying customers.
- There is a compelling case for the DISCOs to also institute AT&C-based load shedding, utilizing the accurate LDI-generated system data, to not just improve their financial viability, but also to help build social pressure against electricity theft and improve customer perception of service reliability and willingness to pay.
- As load shedding has now become more regular and predictable with near elimination of unscheduled outages as an outcome of the LDI project, public perceptions, levels of service satisfaction, and responsiveness and cooperation level with DISCO staff are expected to improve.
- The LDI dataset enables much better system performance monitoring and facilitates the development and adoption of industry "best practices" such as the implementation of KPIs in areas such as outage and tampering reporting, fault rectification, complaint response, AT&C loss reduction, cash recovery index, service quality (e.g., CAIDI, power quality), BEI, and customer satisfaction. In the short-term, the LDI system, with further modifications, can become instrumental in monitoring and evaluation of utility service quality standard.
- With the implementation of AT&C-based load shedding, enabled by LDI system monitoring, utility revenues are expected to increase, which should result in a reduction in the current chronic DISCO revenue deficits and consequently reduce the

circular debt plaguing Pakistan's power sector. However, this requires an appropriate policy directive by the government in this regard.

- Bringing DISCO management and operations to par with internationally accepted standards would greatly improve not just their performance, but also position DISCOs better for eventual privatization, a long running priority objective of the GOP as a means of implementing greater competition and efficiency in the power sector. This would help enhance their net worth and improve government proceeds from the sale transactions.
- The LDI mechanism can help in identifying system strengths and weaknesses, enabling prospective bidders for the DISCOs to more easily formulate responsive solutions and evaluate future prospects. This may result in better assessment of DISCO asset and business value, and help improve investor interest and confidence in the privatization process.
- The LDI system can be integrated with AMI systems on the DISCO grids for reducing system losses, improving revenue recovery and implementing discrete load management at the consumer end as part of "smart metering" initiatives, serving as a first step towards such an initiative in the future.
- Accurate consumption profiles can be drawn for different consumer categories by analyzing LDI data, and tariff designs can be evolved that are aligned with actual usage characteristics of the target consumer groups to determine commercially sustainable retail electricity tariffs in the long-term.
- The LDI metering can help the CPPA, currently affiliated with the NTDC, to fulfill its singular function of a truly autonomous "single buyer" of electricity from grid-connected generators that can enforce contract and transactions according to regulator-defined market rules and ensure proper invoicing and payments. The lack of independent power transaction metering has been one of the main obstacles faced in this regard.
- Additionally, if the government allows DISCOs full freedom in dispatching electricity on the basis of AT&C losses, the CPPA can be entrusted to monitor power distribution by DISCOs as a means of ensuring its revenue receipts from them. The LDI system, in such a case, can provide a ready means of monitoring and controlling power distribution on an optimum basis for reducing AT&C losses.
- There is substantial scope to include electricity end-consumers as beneficiaries of the enhanced information access made possible by the LDI intervention. This would allow consumers to better adjust to power shortages, reduce inconvenience and damages, enhance customer-utility relations, and improve consumers' willingness to pay for service and their interaction and cooperation with utility staff.

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APPENDIX A: CALCULATION OF ECONOMIC IMPACTS OF LDI PROJECT

In order to assess the overall economic impact of the LDI intervention, previous detailed assessments for the effect of power outages on different economic sectors in Pakistan[42] have been employed in this study, with appropriate inflation adjusted updates and modifications to arrive at reasonable first-order approximations. A more thorough, systematic approach employing actual field surveys and other primary data collection was not possible due to time and budget constraints.

The main economic sectors considered are: aggregate (large and small) industrial, commercial, domestic residential, and agricultural. As described in **Section 3.3.2**, a comparison of pre- and post-LDI load shedding patterns shows negligible change in total load shedding amounts in the country (with the natural year-on-year growth in power demand being largely offset by new generation capacity and enhanced availability of extant generation units), but a significant decline in unscheduled load shedding. Thus, the economic impact of the LDI project can be expected to derive from the differential between the effects of planned and unplanned load shedding, as applied to the 1,805 GWh of load shedding shifted from the unscheduled to the scheduled category as a result of better preemptive information made available to grid managers by the LDI facilities. This difference in impacts between the two types of outages is due to the fact that while consumers can tailor their electricity consumption to an extent for planned outages—by, for example, rescheduling activities, protecting equipment and stocks, and arranging for alternative generation, thereby minimizing or averting potential losses—the same cannot be done for unforeseen or unscheduled load shedding, which can thus result in greater losses in incomes, production, stock spoilage, equipment damage and resource underutilization.

The computed amount for the LDI-induced decrease in unscheduled load shedding, i.e., 1,805 GWh, is allocated across the four sectors using an appropriate weightage factor for each sector. These weights are derived from the sector proportion of total power consumption during 2012-2013 (as provided in WAPDA [2011-13]). The following sector reductions in unscheduled load shedding are subsequently arrived at [as detailed in **Table 3.1** of the

[42] Primarily Pasha [2013], supplemented by Pasha [1989], Pasha [2009] and Siddiqui [2011].

accompanying spreadsheet in **Appendix B.1:** Economic Impact (Direct & Indirect) Computation].

Exhibit A.1: Estimated LDI-Induced Sector-Level Reduction in Unscheduled Load Shedding

Category	Total Unit Sales July-December 2013	Relative Weightage Factor	Reduction in Unplanned Load Shedding
	GWh		GWh
Aggregate industrial	18,636	0.29	518
Commercial	4,435	0.07	123
Domestic	34,366	0.53	954
Agriculture	7,548	0.12	210
Total	**64,985**	**1.00**	**1,805**

INDUSTRIAL SECTOR

Pasha [2013] restricts the scope of the analysis to the small-scale industrial sector and importantly does not distinguish between planned and unplanned load shedding when arriving at the costs of power outages. Pasha [1989], on the other hand focuses exclusively on the large-scale, organized industrial sector,[43] but does distinguish between the impact of planned vs. unplanned load shedding. Therefore, for the purposes of quantifying the total economic impact on the aggregated small- and large-scale industrial sector, both Pasha [2013] and Pasha [1989] have been utilized in the current analysis.

Power outage costs in the industrial sector consist of direct costs, which are comprised of spoilage costs and value of lost production (also referred to as the net idle factor cost), as well as adjustment costs, which can include provision of alternative generation, activity and resource rescheduling, etc. In computing the incremental cost of unscheduled load shedding (i.e., differential in the per unit sector impact of unscheduled vs. scheduled load shedding), the proportion arrived at by Pasha [1989] for the small-scale sector has been applied to the entire industrial sector, in the absence of any additional information. This is expected to be a reasonable, even conservative, assumption, as the potential impact of a sudden loss of power is expected to be greater in large volume production processes employing more

[43] Categorized under 'large scale manufacturing (LSM)' by the *Pakistan Economic Survey*, Planning Commission, Government of Pakistan.

sophisticated machinery. However, this may be offset by much of the large scale manufacturing (LSM) sector employing suitable alternative backup generation of its own, although the cost of this (both operational and amortized capital) would also need to be added to the overall adjustment costs. To a first approximation, therefore, a differential overall impact factor of 0.759 computed by Pasha [1989] has been utilized for arriving at the benefit of a reduction in unscheduled load shedding of 518 GWh for the industrial sector, assuming that inflation-adjusted costs do not vary significantly across the two study periods. In reality, energy prices (both grid electricity and alternative generation fuel) have increased in the interval, which should drive the differential upwards, and this should also compensate for any overestimation inherent in applying a uniform differential factor to the overall industrial sector.

In this calculation it is also assumed that the ratios of power outage cost per kWh of unscheduled to scheduled load shedding for the industrial sector and its various subgroups (e.g., textiles, chemicals, food and beverages, etc.) have also remained unchanged over the period between the assessments in Pasha [1989] and Pasha [2013]; these ratios are thus factored into Pasha [2013] costs for overall power outages for the industrial sector and its subclasses to allow for their disaggregation into their corresponding group scheduled and unscheduled differential components, which are presented in **Table 3.8** of the accompanying spreadsheet in **Appendix B.1:** Economic Impact (Direct & Indirect) Computation and shown below.

Exhibit A.2: Estimated Ratios of Planned to Unplanned Power Outages in the Industrial Sector

Industrial Group	Ratio of Unplanned to Planned Outage Costs
Food, beverages and tobacco	3.05
Textiles, apparel and leather	1.25
Wood and wood products	2.59
Fabricated metal products	2.06
Other industries	1.01
Overall	**1.76**

The breakdown of power outages across the study period in terms of the proportion of scheduled and unscheduled load shedding also has to be factored in the computation of the differential per unit cost of unscheduled vs. scheduled power outages for the industrial sector. For this purpose, the total hours of planned and unplanned load shedding were obtained from WAPDA [2011-13], and the corresponding figures for all DISCOs aggregated. The resulting computation shows a total of 212,974 hours of scheduled load shedding (72% of total power outages) and 84,442 hours of unscheduled load shedding (28% of the total) during the period

covered by the data, i.e., July 2013 to February 2014. Calculation details are given in **Table 3.7** of the accompanying spreadsheet in **Appendix B.1:** Economic Impact (Direct & Indirect) Computation.

The values obtained can then be applied to the following equations to obtain the required cost differential per unit impact, ΔC, between unscheduled and scheduled load shedding:

$$\Delta C = C_u - C_s$$

$$C_o = \alpha_s C_s + \alpha_u C_u$$

$$\alpha_s + \alpha_u = 1$$

where:

α_s = Proportion of scheduled load shedding

α_u = Proportion of unscheduled load shedding

C_s = Outage cost per unit of scheduled load shedding

C_u = Outage cost per unit of unscheduled load shedding

C_o = Overall outage cost per unit of load shedding.

Thus, the application of Pasha [1989] cost ratios to the most recent sector outage cost figures reported for the industrial sector in Pasha [2013] allows the additional burden of unscheduled load shedding to be to be calculated as Rs 30.69/kWh, as shown below.

Exhibit A.3: Estimated Impact of Planned Vs. Unplanned Load Shedding in the Industrial Sector

Industrial Group	Overall Outage Cost	Outage Cost for Planned Load Shedding	Outage Cost for Unplanned Load Shedding
	Rs/kWh	Rs/kWh	Rs/kWh
Food, beverages and tobacco	61.50	38.91	118.48
Textiles, apparel and leather	46.60	43.57	54.25
Wood and wood products	68.10	46.90	121.57
Fabricated metal products	34.40	26.46	54.42
Other industries	53.00	52.89	53.29
All Sectors	**50.50**	**43.01**	**73.70**
Additional Cost of Unplanned Load Shedding			**30.69**

The aforementioned outage cost differential of Rs 30.69 per kWh is multiplied by the reduction in unscheduled load shedding of 518 GWh estimated to result as a direct consequence of the LDI project (**Exhibit A.1**) to obtain its total annual monetary benefit accruing to Pakistan's industrial sector of Rs 15.9 billion ($156.6 million).

RESIDENTIAL SECTOR

The methodology for quantifying the per-unit outage cost differential for domestic residential electricity consumers is qualitatively different from that used for the industrial sector. Relevant analyses of the cost of power outages for the domestic sector in Pakistan do not distinguish between scheduled and unscheduled load shedding impacts. In the absence of such differentiation, it is pertinent to examine the approach employed by Pasha [2013]. This study categorizes domestic sector outage costs into three categories: "monetization of utility loss", "cost of self-generation", and "other costs". Monetization of utility loss estimates the subjective valuation by households of the cost of outages to them based on their professed willingness to pay a higher tariff for uninterrupted electricity supply, while the cost of self-generation measures the additional expense of obtaining power through a generator or UPS. Other costs comprise spoilage costs, damage to appliances, and other miscellaneous costs. The approach employed is therefore a hybrid of a standby generation cost-based approach and a willingness-to-pay approach, but is constrained in its application for this study owing to its lack of distinction between scheduled and unscheduled load shedding impacts.

In order to arrive at this distinction, it is assumed that during unscheduled load shedding, the outage cost component for self-generation and the monetization of utility loss (i.e. the operational costs of generators and UPS) would remain unchanged, whereas the other costs would increase compared to the scheduled load shedding case. This increase in only one component of the outage cost drivers for unscheduled outage impact is conservatively taken to be 25%. The overall differential, in the absence of no change in the other two cost drivers for this sector, is therefore constrained to be much less than 25%, which is not an unreasonable amount (compared to the 76% differential for small-scale industry calculated in Pasha [1989]). Using this factor, the figure for unscheduled outage costs for the residential sector is calculated to be Rs 20.55/kWh. For scheduled load shedding, the corresponding figure is Rs 19.80/kWh, resulting in a differential cost between the two of Rs 0.74/kWh. It is pertinent to mention here that this analysis makes the provision that the calculated outage costs for scheduled and unscheduled load shedding, when factored with the proportions of schedule and unscheduled load shedding, would equal the overall outage cost for load shedding to the domestic sector consistent with the figure in Pasha [2013].

Exhibit A.4: Breakdown of Outage Costs by Type of Outage for Different Domestic Sector Household Income Categories

Household Income	Outage Cost: Planned Load Shedding	Outage Cost: Unplanned Load Shedding
Rs/Month	**Rs/kWh**	**Rs/kWh**
0-15,000	17.74	19.82
15,001-35,000	28.79	30.94
35,001-70,000	27.10	28.13
70,001 and above	15.79	16.04
Overall	**19.80**	**20.55**
Cost Differential Between Unplanned and Planned Load Shedding		**0.74**

Applied to an annual reduction of 954 GWh in unscheduled load shedding for the residential sector (**Exhibit A.1)**, an economic dividend of Rs 708.7 Million ($7 Million) is estimated as a direct benefit of the LDI project for domestic electricity consumers in the country.

COMMERCIAL SECTOR

Similar to the industrial sector, Pasha [2013] computes outage costs to the commercial sector by categorizing them into direct costs, i.e., the value of lost production (referred to as net idle factor cost) spoilage costs, and indirect costs, which are primarily comprised of the cost of self-generation. In the absence of a quantitative bifurcation of costs into scheduled and unscheduled load shedding impacts, the differential is computed here by assuming that spoilage costs and net idle factor costs would increase by at least 25% in the case of unscheduled load shedding, with indirect costs remaining largely unaffected. Again, this would be a conservative estimate, given that commercial sector unplanned outage losses would be proportionately higher than those for the residential sector and closer to the differential for small-scale industry, assessed by Pasha [1989] to be 76%.

After summing the upward-adjusted net idle factor and spoilage costs, and adding the unchanged self-generation costs, a figure is obtained for the overall outage cost of unscheduled load shedding for the commercial sector in Pakistan. Corresponding values are also derived for scheduled load shedding, and provision made during the computation so that the weighted average of the recalculated costs for scheduled and unscheduled load shedding would equal the overall outage cost of load shedding given in Pasha [2013].

Exhibit A.5: Breakdown of Outage Costs for Different Commercial Sector Categories

Category	Net Idle Factor Cost for Planned Load Shedding	Net Idle Factor Cost for Unplanned Load Shedding	Spoilage Cost for Planned Load Shedding	Spoilage Cost for Unplanned Load Shedding	Generator Costs
	'000 Rs/kWh	'000 Rs/kWh	'000 Rs/kWh	'000 Rs/kWh	'000 Rs/kWh
Wholesale & retail trade	62.56	78.20	9.34	11.67	24.00
Restaurants & hotels	53.22	66.53	8.40	10.50	50.00
Transport & communications	144.73	180.91	2.80	3.50	51.00
Finance and insurance	38.28	47.85	–	–	21.00
Community, social and personal services	43.89	54.86	1.87	2.33	44.00
Total	**61.63**	**77.03**	**6.54**	**8.17**	**32.00**

The aforementioned procedure effectively allows for a split of the overall cost computed in Pasha [2013] into its scheduled and unscheduled components, as shown below:

Exhibit A.6: Breakdown of Outage Costs by Type of Outage for Different Commercial Sector Categories

Category	Outage Cost Planned Load Shedding	Outage Cost Unplanned Load Shedding	Outage Cost
	Rs / kWh	Rs / kWh	Rs / kWh
Wholesale & retail trade	57.42	68.19	60.50
Restaurants & hotels	66.05	75.17	68.60
Transport & communications	96.84	114.83	101.90
Finance & insurance	61.12	70.98	63.90
Community, social and personal services	77.37	87.23	80.20
Total	**73.62**	**85.72**	**77.06**

The outage cost differential per unit for unscheduled vs. scheduled load shedding in the commercial sector is thus calculated to be Rs 12.10. This value, multiplied by the annual decrease in unscheduled load shedding allocated in the commercial sector of Rs 123 GWh (**Exhibit A.1**) provides a value of Rs 1.49 billion ($1.47 million) in terms of the economic benefit of the LDI intervention for Pakistan's commercial sector.

AGRICULTURAL SECTOR

According to Pasha [2013], electricity consumption, and the associated cost of load shedding, in the agricultural sector is dominated by tube well use and, to a lesser extent, by income generating household activities, such as dairy or poultry production. Given the absence of standby generation availability for the sector, power outages can adversely impact agricultural output by reducing water availability owing to tube well shutdowns. However, the cumulative non-load shedding hours during a day generally exceed the average daily duty cycles of the agricultural tube wells and, therefore, tube well use can be assumed to be non-time critical, i.e., tube well operation hours lost due to load shedding can be made up for at other times of the day and night. Therefore, there would be negligible differential impact of unscheduled vs. scheduled load shedding in terms of farm output, provided overall load shedding (and therefore total tube well operation hours) does not change significantly. Similarly, other productive uses of electricity in the agricultural sector, given the general absence of refrigerated storage of dairy and poultry produce at the production end of the supply chain in Pakistan, is not expected to be affected differently by unscheduled vs. scheduled load shedding.

It is therefore assumed that the reduction in unscheduled load shedding, with overall load shedding remaining unchanged, would not significantly affect Pakistan's agricultural value addition activities. In the absence of further cost drivers, the cost impact differential between unscheduled and scheduled load shedding is therefore assessed to be negligible in this case.

APPENDIX B: SPREADSHEET ANALYSIS OF ECONOMIC COSTS OF POWER OUTAGES

Electronic spreadsheets provided separately:

Section B.1: Economic Impact (Direct & Indirect) Computation

Section B.2: Inter-DISCO Reallocation Computation

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