IMPROVING THE EFFICIENCY OF

THE ELECTRICITY BILLING SYSTEM

IN PAKISTAN

Afia Malik, Tehmina Asad, and Ghulam Mustafa

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Pakistan Institute of Development Economics

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EXECUTIVE SUMMARY

Electricity billing irregularities are common among distribution companies (DISCOs) in Pakistan. The electricity system has faced a financial deficit for about 18 years, mainly due to high technical and non-technical losses, and outdated infrastructure affects electricity supply reliability.

Energy is a complex field that requires smart solutions. Utilities worldwide are adopting smart billing systems to reduce losses, enhance accuracy, and improve reliability. Experience shows that smart meters can help minimise losses and inform consumers about their electricity usage.

The study outlines the existing manual billing system, highlighting its inconsistencies, challenges, and costs. Based on a survey of 2,000 consumers, including households, businesses, and industries in Rawalpindi, Islamabad, Lahore, Multan, Faisalabad, and Sukkur, the study found that 79 per cent of the respondents were willing to switch to an advanced metring system and pay for this transition.

In another survey of 800 consumers—400 from LESCO and 400 from MEPCO—the study found that smart meters were ineffective where consumers' consent and opinions were overlooked. Effective outcomes require prior knowledge of smart meters.

In regions where these conditions are fulfilled, consumers tend to be significantly more satisfied as their billing discrepancies diminish, electricity supplies become increasingly reliable, and they can lower their electricity consumption. The study found that consumers using smart meters and increased awareness can achieve an average electricity savings of up to 17 per cent.

If consumers assume responsibility for the initial costs associated with smart meters, the study estimated that the payback period for various types of smart meters will remain within two years. In other words, there are potential net benefits in the remaining life of the smart meter.

From the utilities' perspective, LESCO's projected savings with smart meters (AMR) from FY2016-17 to FY2023-24 on three loss-making 11KV feeders (Ali Hajvari, Madina Town, and Sabzi Mandi) were found to be PKR 960 million. Similarly, MEPCO generated PKR 2.2 billion of extra revenue in 11 months with 150,000 smart meters.

The study suggests that a smart meter is the solution for checking billing irregularities, reducing power sector losses, and improving grid reliability. Consumers are willing to invest in smart electricity meters provided they are aware of their potential benefits. They should have the option of selecting between one-time payment or monthly instalment plans on their electricity bills.

Significant variations exist in the prices of imported smart meters compared to those sold by local vendors. An open market for smart electricity meters should be established, mirroring the framework of the smartphone market. Consumers must be free to choose the smart meter that best meets their preferences and system specification standards.

As the nationwide deployment of smart meters commences and market competition intensifies, economies of scale are expected to drive down their prices.

Empowering consumers is critical for unlocking smart meters' full potential. This objective can be achieved by integrating a mobile application that operates in conjunction with smart meters.

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1. INTRODUCTION

1.1. Background

In July and August 2023, the National Electric Power Regulatory Authority (NEPRA) received several complaints of excessive billing and meter reading irregularities across all electricity distribution companies (DISCOs). NEPRA conducted an inquiry and found serious billing and meter-reading irregularities across all DISCOs, which led to overbilling for consumers.

According to the report, more than 8 million consumers were charged for more than 30 days of the billing cycle in July 2023. In August 2023, 5.7 million were charged for more than 30 days of billing cycle. As a result, consumers moved from lower to higher slab, increasing their per unit cost of electricity. Furthermore, about 1.1 million were served with electricity bills with invalid snaps during these two inquiry months (Figure 1).

The NEPRA Inquiry Report further states that according to the notified tariff terms and conditions, the billing period means a billing month of 30 days or less reckoned from the date of the last meter reading. However, in July and August of 2023, the billing cycle carried out by DISCOs ranged between 30 and 40 days, even more in some cases, which led to over-billing for end-consumers.

NEPRA charged DISCOs for these irregularities, while DISCOs (current and former DISCO officials) blamed bureaucratic controls (Power Division) for these billing irregularities. This is not the first time such anomalies have been detected. Malik (2012) cited two reports (one by Haigler Bailly, Pakistan, and the second conducted under a US-funded power distribution improvement programme), which illustrate that Pakistan's power sector (public sector) lost over PKR 391.6 billion every year mostly because of mismanagement; power companies have been over-billing consumers, making recovery difficult.

Box 1. Number of Domestic Consumers with Excessive Billing

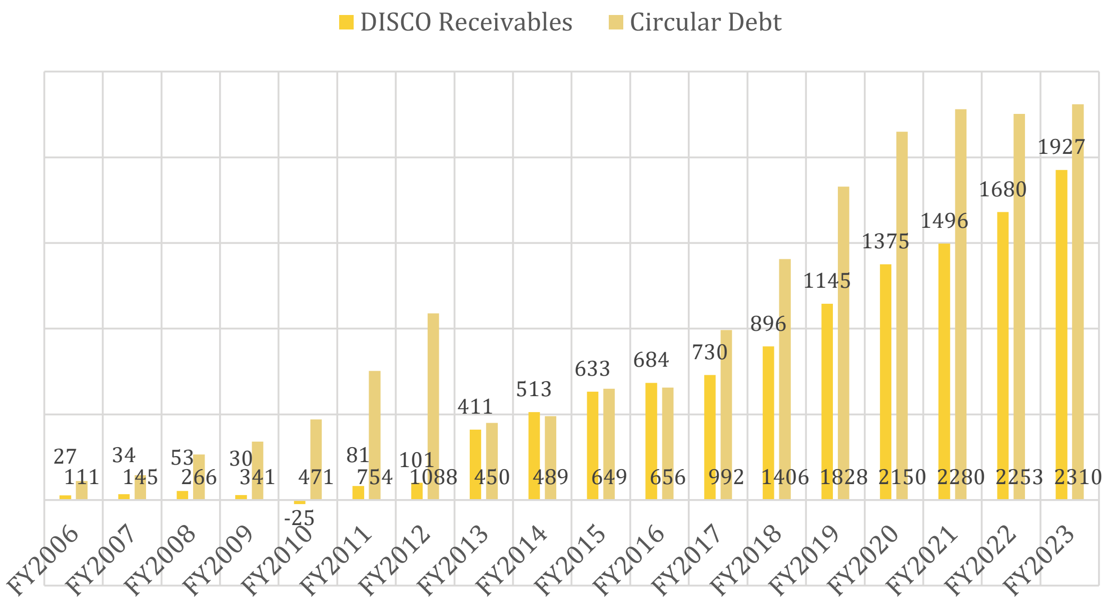
DISCO	Billing Month	Reading Period More than 30 days	Consumers Charged Higher Slab due to Excessive Reading Period	Consumers Converted from Protected to Non-protected	Consumers whose Lifeline status changed to Non-Lifeline	Consumers without Valid Meter Reading/Snap Date
MEPCO	July 2023	5,725,048	2,137,973	647,155	40,668	15
	August 2023	2,265,271,	230,746	32,190	3,515	138,723
GEPCO	July 2023	463,360	61,439	20,526	618	57
	August 2023	1,192,062	157,202	30,510	1,211	43
FESCO	July 2023	354,904	60,169	18,368	157	10
	August 2023	844,058	237,971	34,273	757	9,694
LESCO	July 2023	685,588	88,321	19,336	2,020	123,440
	August 2023	650,460	69,692	10,700	1,662	126,014
HESCO	July 2023	521,624	113,640	15,736	1,181	94
	August 2023	208,481	13,727	1,541	160	39,362
PESCO	July 2023	156,647	9,810	4,411	238	2,875
	August 2023	156,949	11,530	3,305	272	638
QESCO	July 2023	116,255	3,719	856	153	116,255
	August 2023	48,732	2,335	353	34	48,732
IESCO	July 2023	17,009	6,529	1,237	42	1,848
	August 2023	28,841	2,134	363	21	68
SEPCO	July 2023	485	20	1	0	485
	August 2023	325,764	5,158	542	91	325,764
KE	July 2023	Nil	Nil	Nil	Nil	77,869 (inaccurate snap)
	August 2023	Nil	Nil	Nil	Nil	65,675 (inaccurate snap)
TESCO	July 2023	-	-	-	-	-
	August 2023	-	-	-	-	-

Source: NEPRA (2023a).

Billing irregularities have been typical in all DISCOs for a long time in Pakistan. Furthermore, Pakistan's electricity system has faced a financial deficit for about 18 years (Figure 2), in which high technical and non-technical losses have been the main contributors (Table 1). There are issues of system reliability due to outdated infrastructure as well.

Energy is a complex, multi-layered, and multi-dimensional field, that demands smart energy solutions. Smart (automated) billing systems are being increasingly adopted by utilities globally to reduce system losses and to improve billing accuracy and overall system reliability and efficiency. Global experience suggests that smart meters can help reduce losses and inform consumers about electricity consumption. Thus, it acts as a tool to manage demand and save energy.

Figure 1. Financial Losses (PKR Billion)



Source: Power Division, NEPRA State of Industry Reports (Various Years), and Cheema et al. (2022).

Table 1. Financial Losses - Circular Debt (PKR Billion)

	FY2022	FY2023	Jul-Jan 2024
Payable to Power Producers	1,351	1,434	1,760
GENCO Payable to Fuel Suppliers	101	111	111
Amount Parked in PHL	800	765	765
Total	2,252	2,310	2,635
Break-up of increase			
Budgeted but unreleased Subsidies	-12		-3
Unclaimed Subsidies	-133	70	--
Interest Charges (PHL+ IPP)	134	143	72
Pending Generation Cost (QTA +FCA)	414	250	214
Non-Payment by KE	107	-53	11
DISCO Losses	133	160	86
Under Recoveries	180	236	198
Prior Year Adjustments	-285	-447	-116

Source: Power Division (Ministry of Energy).

Smart meters have been suggested in Pakistan for long. However, the lack of financial resources and resistance from stakeholders are hindering the movement towards smart energy solutions, such as pre- or postpaid smart meters.

In Pakistan, a few pilot projects were completed (e.g., in MEPCO, LESCO, and PESCO) in the past and a few more have been initiated (e.g., in IESCO) with the help of donors' financial and technical assistance. However, this is not a sustainable approach. Many countries are implementing smart metering infrastructure to reduce inconsistencies with the support of consumers themselves.

This study is designed to highlight the current system's inconsistencies and challenges, estimate the transition cost, and determine whether consumers are willing to bear these expenses through bills instead of relying on loans from donors that come with certain conditions and are not sustainable in the long run. The study intends to help policymakers develop a comprehensive plan to overcome financial and technological challenges facing electricity distribution utilities and the entire sector. In Pakistan, fossil fuels are heavily used for electricity production, resulting in costly imports and shortages. Smart meters can help make energy conservation easier.

1.2. Study Objectives

This study aimed to look into the billing process in Pakistan while focusing primarily on Islamabad Electric Supply Company (IESCO), Lahore Electric Supply Company (LESCO), and Multan Electric Power Company (MEPCO). The study intends to achieve the following objectives:

1. To explore the billing process in Pakistan to understand and find the exact source of irregularities in consumer-end billing.
2. To estimate the cost of converting a manual metering system to a smart (automated) metering system, calculate the total financial costs associated with smart meter installation per connection.
3. To investigate the consumer willingness to adopt and pay for this transition.
4. To assess the impact of smart metering infrastructure on billing accuracy, billing simplicity, consumer satisfaction, and impact on theft and recoveries.
5. Recommend a phased implementation plan for smart meters across the country.

2. CONCEPTUAL FRAMEWORK

2.1. Electricity Billing Mechanism in Pakistan

Currently, electricity consumption monitoring in Pakistan relies heavily on manual labour, particularly the meter-reader/ lineman who painstakingly records the meter reading of each household. This method, however, is proving to be increasingly time-consuming and labour-intensive, especially with the expanding consumption areas. It is also susceptible to human malpractices, leading to inaccuracies, irregularities, and errors in the consumer-end billing system. This, in turn, makes it challenging to detect instances of electricity theft. In some cases, it becomes the source of meter-tempering or paying a fixed amount irrespective of units consumed.

On the other hand, consumers are billed without knowing their real-time usage, which makes them apprehensive about the meter-reader or the utility company's behaviour. Additionally, consumers cannot track their hourly power consumption or plan their use to save energy and economise on their electricity bills.

The present system has increased the likelihood of technical and non-technical losses manifold. Pakistan's electricity system has been facing a financial deficit, known as circular debt, since 2006. High technical and non-technical losses are one of the contributors. Moreover, there are issues of system reliability due to outdated infrastructure.

Electricity meters are devices used to measure electricity consumption. Modern technologies are now being used for this purpose. Some countries are replacing conventional meters with smart meters to improve electricity measurement accuracy, efficiency, and privacy (Bimenyimana & Asemota, 2018). Around the world, many countries and utility companies are upgrading their power grids and replacing conventional meters with smart meters, allowing for calculating and recording hourly electricity consumption.

2.2. What are Smart Meters

Smart meters are digital devices that record real-time electricity[1] consumption and relay the information to utility companies. Smart meters are different from traditional digital meters. Digital meters can record power usage in 30-minute intervals, but they cannot transmit this information to the service provider. They necessitate manual reading or periodic data downloading. Smart meters can record and communicate real-time data to the utility without manual support. In Pakistan, currently, meters installed in most areas are digital meters. Although digital meters have many features, they are not fully smart meters.

2.2.1. Smart Meter Types

Automated Meter Reading (AMR) and smart meters (SMETS- Smart Metering Equipment Technical Specifications) have similarities but operate using different technologies. AMRs have a SIM in them that transmits data over a mobile network, whereas smart meters (with two-way communication) use a communications hub – Advanced Metering Infrastructure (AMI). AMI is a hub for incoming data from all installed smart meters. The most advanced SMETS2 meters have the highest data security.

AMR also communicate energy consumption data to a central network without the need for manual readings. Unlike smart meters under the AMI system, AMR offers only basic energy usage information to customers, real-time two-way communication is not possible. They lack advanced energy management capabilities compared to AMI systems. Even less advanced AMRs require data collection using portable devices near the meters.

2.3. Conventional vs Smart meters

In the case of traditional meters, there is no facility for data storage, and electricity consumption is measured physically by the meter reader. Sometimes,

[1] Smart meters can also be used to record gas or water consumption.

if the meter reader has no access to the meter, this might lead to estimated billing. If there is an interruption in the electricity supply, the DISCO cannot respond promptly. Conventional meter connections and disconnections require manual handling (Originenergy, 2015).

Additionally, in traditional monitoring, human labour is heavily involved in collecting and managing electricity consumption data. This method has become time-consuming, labour-intensive, and error-prone due to the increasing size and spread of consumption areas (Yin, 2012). The traditional meter only shows the amount of electricity the consumer uses since the last reading taken by the meter reader.

In contrast, smart meters provide accuracy, visibility, and privacy, substantially reducing the likelihood of human error. The availability of real-time data enables informed decision-making and a more proactive approach toward energy management. It allows for the optimum allocation of resources, reducing electricity wastage and, in turn, its negative environmental impact.

Smart meters can store data hourly (in some cases half-hourly) and send it to the DISCO automatically. Electricity consumption data and time-of-use are accessible in real-time. In case of electricity supply interruption, DISCOs can respond more quickly than with a conventional meter. Due to remote management, smart meters also allow for faster connections and disconnections (Popa, 2011). Some of the benefits of smart metering infrastructure are listed in Box 2.

Box 2. Advanced (Smart) Metering Infrastructure

Two-way Communication:

AMI enables two-way communication between utilities and end-users for dynamic demand response, grid monitoring, and fault detection.

Consumers can also monitor their consumption and load through an app on their smartphones at any time of the day.

Grid Optimisation:

Utility providers can optimise grid planning and ensure reliable electricity supply by collecting and gaining insights into granular demand patterns.

Reduces the need for new power plants and increases the efficiency of the existing power system while lowering greenhouse gas emissions.

Reduces blackouts and system failures.

No Billing Delay, Human Error, or Malpractices:

Unlike traditional meters, it does not require meter readers; it records electricity consumption, voltage levels, and load.

It automatically transmits the consumption and load data to the utility company in real time, eliminating delays or human errors.

Awareness & Informed Decision-making:

Smart meters provide utilities and consumers with detailed, real-time data, enabling them to make informed decisions, encouraging energy awareness, and leading to proactive management. This optimises resource allocation, reduces energy waste, and mitigates environmental impact.

Smart meters are an integral part of the smart grid ecosystem.

Real-time data availability ensures precise billing, providing consumers with insights into their energy usage patterns and empowering them to make informed decisions to save on electricity units and economise on their bills.

Smart meters help customers save money by using time-of-use tariffs to shift their electricity usage to off-peak hours, reducing strain on the grid and optimising their bills.

Remote Management:

Utility companies can remotely detect faults, perform diagnostics, and address issues promptly, enhancing operational efficiency and minimising downtime, eliminating the possibility of transformer or meter failures or fires.

Tamper Detection:

Smart meters are equipped with sensors that can detect any wrongdoing and alert utilities to take prompt action remotely.

Authentication and Encryption:

Smart meters employ strong security protocols, including authentication mechanisms and data encryption, to ensure the integrity and confidentiality of communication between the meter and utility systems.

Dynamic Pricing:

Provides an easy option for dynamic pricing, increasing or decreasing electricity prices in response to demand.

Table 2. Conventional vs Smart Meters

	Traditional Metering System	Smart Metering System (GSM-based)	Smart Metering System (GPRS-based)
Real-time Meter Reading	No	Yes	Yes
Real-time Monitoring	No	Yes	Yes
Energy Theft Prevention	No	Yes	Yes
Communication Medium	None	GSM	GPRS
Two-way Communication	No	Yes	Yes
Cost-effectiveness	High	Moderate	Moderate
Complexity of Installation	Low	High	High

Table 3. Application of Smart Metering Data with Description of Different Component Technologies Employed

Application	Sensing	Smart Grid Measurement	Communication Protocols
Load Forecasting	Voltage, Current, & Power	Aggregation at various levels such as locality, substation and transmission	Cellular for Data Aggregation and Local Networks such as Bluetooth for Home Aea data Collection
Theft Detection	Complex Power	Phasor measurement, Synchro-phasers, RAPD	NB-IoT, 4G, 5G, & Wi-Fi
Anomaly Detection	Complex Power, Voltage, Current, Phase	Phasor measurement, Synchro-phasers, Waveform analysis, RAPD	Cellular and Wi-Fi
Consumer Profiling	Waveform Analysis	Waveform analysis,	Cellular, Wi-Fi, ZigBee, LoRa
Activity Detection	Power, Voltage, Current, Waveform	Waveform analysis,	Cellular, LoRa, Bluetooth, Wi-Fi
Fault Detection	Power, Voltage, Current,	Waveform analysis, Power Quality, Differential Phasors	Cellular, NB-IoT, Wi-Fi

Source: Rind et al. (2023).

Smart meters enhance energy management efficiency and cost-effectiveness by eliminating the need for manual meter reads. They offer accurate data for billing, detecting and reporting tampering or fraud, and enable customers to track their consumption effectively. Additionally, they can prevent widespread blackouts by turning off certain loads during high-demand situations (He, 2016).

2.3.1. Smart Meter Challenges

Smart meters involve a multifaceted arrangement. They communicate bidirectionally with the host digital terminal (HDT), which manages the meters, communication network, and data acquisition. The HDT also handles configuration and firmware updates of the meters. It is an interface connected to meter data management (MDM) software via a common bus (Misra, 2024).

The Meter Data Management (MDM) system validates, analyses, and extracts value from a large amount of information for utility applications. The modules in MDM encompass billing, customer services, grid operations, and support for demand versus supply planning. Integrating and running this system is complex due to the various layers of hardware (millions of devices), communication modules and networks, HDT, MDM, consumer mobile applications (apps), and tools for utility maintenance personnel (Misra, 2024).

Running this complex system also raises challenges, including seamless integration, reliability, obsolescence, maintenance, change management, staff training, and consumer awareness (Misra, 2024). The deployment of smart meters poses major challenges related to privacy and security, requiring crucial government support to resolve these issues (Strong, 2017).

Yet, the main obstacle to adopting SM is its high cost and relatively shorter lifespan, in contrast to the 30 to 40 years of conventional meters (Misra, 2024). Furthermore, infrastructure costs, installation complexities, smart grid availability, and network coverage are among the major challenges. Consumer awareness and acceptance is also crucial for its successful implementation (Hussain et al. (2016).

2.4. Smart Meters and Consumer Behaviour

With traditional electricity meters, consumers have been passive actors in the electricity system. However, technologies like automated metering infrastructure allow for their greater involvement. New technologies have enabled them to manage their energy consumption. They will likely change their behaviour to become more responsible energy users.

Advances in energy-related technologies are expected to bring significant social changes in modern societies. Users must take a proactive approach to seize the opportunities offered by new technologies (Batalla-Bejerano et al., 2020). Smart metering can be a game-changer! By embracing it, consumers can transform their energy consumption habits and realise substantial energy savings.

Access to real-time consumption data through a mobile app or a meter has opened new possibilities for users to decide when and how to interact with the electricity system. This development is not just about consumer empowerment but also about the potential for new business opportunities and system services, which are likely to emerge, leading to more active consumer participation.

Electricity is often used inefficiently, with most consumption occurring during peak hours. This high demand requires costly additional generation capacity, ultimately increasing consumer costs. Demand management strategies, such as "time of use" (ToU), encourage shifting energy usage to off-peak hours but are not always applied to all consumers. Smart meters detect loads exceeding their sanctioned limit and enable consumers to modify energy consumption patterns to reduce costs (Martinez-Pabon et al., 2017).

Demand-side management (DSM) involves actively managing energy demand. It includes the following components:

- Peak clipping -users respond to pricing or energy information feedback, reducing peak energy demand.

- Load shifting - consumers shift energy consumption from peak to off-peak periods.
- Strategic conservation - engaging in activities to reduce energy consumption (Cited from Batalla-Bejerano et al., 2020).

Consumer acceptance of smart metering technology is not well-researched. Only a few studies have examined the criteria for technology acceptance. Knayer & Kryvinska (2022) conducted a thorough literature review on adopting smart metering technology at household and organisational levels. The findings suggest a lack of evidence-based research on consumer preferences. The study concludes that it is essential for policymakers to promote wider technology adoption by highlighting the benefits, especially since the technology is still in its early stages.

2.5. Smart Meters: Improving Operational & Commercial Performance

Smart Meters (SM) technology can help resolve challenges faced by energy utilities and consumers. It is highly effective in detecting non-technical losses (NTLs), which correspond to non-billed energy injected into the network due to electricity theft, measurement errors, metering faults, etc. It helps prevent technical & non-technical losses (theft) by deterring customers and utility personnel from cheating, which is common with traditional meters.

In developing countries (including Pakistan), electricity theft is widespread. The main advantage of implementing smart metering technology is often managing electricity theft rather than energy conservation. This indicates that any rise in reported electricity consumption (initially) due to smart metering may be because of the high incidence of electricity theft, meter tampering, meter bypassing, reading errors, and problems with defective and ageing meters. All of these factors contribute to utility losses, especially non-technical losses.

In 2019, a utility company in Ghana initiated a non-technical loss reduction programme by replacing postpaid meters with smart prepaid meters that are anti-tamper, anti-fraud, and anti-theft. Otchere-Appiah et al. (2021) used customer-level residential billing panel data from 2018 to 2019 to assess the effectiveness of this programme using a fixed-effect approach. The results revealed that by replacing tampered postpaid meters with smart prepaid meters, the reported amount of customers' monthly electricity consumption increased by 13.2 per cent when any tampered postpaid meter was replaced with a smart prepaid meter. This significant increase indicates the extent of non-technical losses by customers. It also suggests that smart prepaid metering holds great promise as a solution for reducing these losses in areas where electricity theft is rampant.

In a study, Athanasiadis et al. (2023) reviewed the use of smart meter data in distribution networks. Focusing on six areas, i.e., forecasting demand, reducing losses, managing assets, planning the power system, identifying connections, and analysing operations, the study suggested that analysing smart meters and demographic data can improve forecasts and provide insights into electricity usage. In India, Marimuthu et al. (2018) found that smart meters offer multiple benefits, including improved metering accuracy, theft detection, and increased consumer awareness of energy consumption.

Barua & Goswami (2020) analysed energy consumption from 500 randomly selected households with smart meters in Guwahati. They found that smart meters allow consumers to monitor their power usage in real time, leading to responsible consumption while enabling suppliers to manage and distribute electricity efficiently. The study also noted a strong correlation between household electricity usage and weather conditions.

In 2014, a study was conducted on developing and testing methodology for smart metering infrastructure across various EU members. The findings suggested improved operational benefits of smart meters, such as enhanced metering accuracy, theft detection, and increased consumer awareness of energy consumption. The study emphasised the importance of standardised testing methodologies to ensure the reliability and interoperability of smart metering systems (European Union, 2014).

In another study in the same year, multiple pilot projects were reviewed to comprehend the challenges and successes experienced across different regions. The study provided insights into the technological advancements, consumer responses, and operational efficiencies realised through these pilot projects and identified key factors contributing to the successful implementation of smart meters. These factors include effective stakeholder engagement, robust communication infrastructure, and comprehensive consumer education programmes (cited from European Union, 2014).

The literature generally suggests that smart meters benefit distribution utilities and consumers. The full integration of smart meters could result in improved revenue collection, enhanced demand-side management, and better quality of electricity supply. The benefits of the smart meter implementation programme are typically measured in terms of loss reduction, billing efficiency, and increased revenue.

- DISCOMs in Uttar Pradesh claim a net benefit of INR 40.56 billion over eight years due to improvement in billing efficiency (Mandal, 2020).
- It helped reduce about 20 per cent in non-technical losses in Mozambique, increased debt repayment and bill recoveries in the UK and Australia, and demand management in Canada and the US (Cheema et al, 2022).

2.6. Smart Meters for Energy Efficiency and Integrating Renewables

The current shift towards a decarbonised economy is prompting us to reconsider the functioning of the existing electricity system (IEA, 2018). The increasing use of renewable energies and the growth of electric vehicles are significantly changing how the power grid operates. The crucial element in this transformation is effectively managing different energy flows to support the system with greater flexibility. In this transformation, smart meters are pivotal in improving the system's efficiency, reliability, and security (Martinez-Pabon et al., 2017) (cited from Batalla-Bejerano et al., 2020).

Furthermore, with the increasing use of rooftop solar under net-metering/net-billing schemes, challenges have emerged due to reverse power flow, generation unpredictability, power quality, and voltage regulation. Conventional grid infrastructure is typically designed for one-way electricity flow. These distributed generation facilities are causing operational problems such as voltage spikes, damaging equipment, and potentially destabilising the grid. Additionally, having too many solar PV systems in a specific area could overwhelm the local grid, leading to potential grid stability issues due to excess energy. AMI can overcome all these grid challenges through improved monitoring and oversight. It allows for better oversight of actual network management capacity (Malik & Rehman, 2024).

Smart meters are crucial for transitioning to a cleaner, more efficient energy system and achieving net-zero carbon emissions by 2050. This technology is vital in modernising energy use, transforming the retail market to better serve energy consumers, and eliminating the need for manual meter reads and estimated billing. The data recorded by smart meters, such as half-hourly energy consumption and price data, drives new approaches to managing demand. Innovative products like smart 'time of use' tariffs reward bulk customers for using energy during off-peak times. Furthermore, they enable the cost-effective integration of technologies such as electric vehicles and smart appliances with renewable energy sources (Carbon Architecture, 2023).

Using smart meters can contribute to energy efficiency and help build a low-carbon future. Rausser et al. (2017) studied electricity consumption in EU countries and the use of smart meters by households and businesses to reduce energy costs. The study involved pre-trial and post-trial surveys, with 4,232 households in the pre-trial and 3,423 households in the post-trial phase. The findings suggest that households using smart meters are likely to change their consumption patterns to benefit the environment. Additionally, energy savings are more relevant for renters.

2.7. Smart Meters and Its Costs

Smart meters are part of an AMI system, which also includes communication networks and data management. Compared to a centralised conventional billing system, a smart metering system (prepaid or postpaid) linked to the DISCO-level billing system enables the proper and transparent flow of information and revenue. However, transitioning from the conventional metering system to the new AMI system would require high capital investments to ensure overall functionality beyond traditional meters' capabilities (Cheema et al., 2022; Strong, 2017).[2]

In the beginning, they may involve some extra costs, such as personal training, developing new equipment with new technology, financial agreements for software development, and the cost of data collection and storage, along with security and installation fees (Weaver, 2015; Kim et al., 2011). Nevertheless, once the system is developed, these taper off. Moreover, the AMI costs are outweighed by its long-term benefits, which include consumer savings, operational efficiencies, and better customer service (Strong, 2017). The benefits of AMI are estimated to be 6.6 times higher than the cost (Shah & Khan, 2017).

2.8. Global Perspective

It's worth noting that power utilities worldwide also face similar challenges. Yet, utilities in developed and developing countries are increasingly adopting automated billing systems to improve accuracy, system efficiency, and scalability. These systems integrated with smart meters can provide valuable insights for better consumer and utility decision-making.

The growing use of smart meters is driven by digital transformation and technological innovation as utilities grapple with ageing infrastructures, evolving regulations, and rising consumer expectations.

[2] A case study of the PESCO feeder.

Digitisation and integration of information and communication technology (ICT) have now been realised as crucial drivers in enhancing efficiency in the energy system, enabling smarter living and human-centric development (Rind et al., 2023).

Box 3. Global Smart Meter Market

The global smart meter market was valued at USD 21,810.14 million in 2023 and is expected to grow by over 9% in the next decade. The increasing use of smart meters is a prime example of the digital transformation in the energy industry. As electric utilities worldwide deal with outdated infrastructures, changing regulatory obligations, and rising consumer demands, implementing smart metering solutions has gone beyond just upgrading operations to becoming a crucial strategic move.

Smart meters have become increasingly significant in the utility and energy sectors due to the trend towards sustainable and efficient energy consumption models. These advanced devices are equipped with real-time data collection and communication capabilities, making them essential in modernizing energy infrastructures worldwide. Enhanced energy management and conservation are driving the expansion of the smart meter market globally.

Source: PMR (2024).

Furthermore, with the increasing integration of renewable energy sources and distributed generation technologies, it becomes challenging for utilities to balance the supply and demand of electricity in real time. Monitoring installed DG capacity manually is factually impossible. Only through automated metering infrastructure and smart meters, it is possible to monitor the actual capacity installed and to remotely control input and output, and disconnect in case of grid frequency issues. Smart meters can increase grid visibility and control any system connected to the grid remotely (Malik & Rehman, 2024).

2.8.1. Global Experience with Smart Meters

Hussain et al. (2016) report that the world economy suffers a staggering USD 89 billion yearly loss due to electricity theft, billing irregularities, and the destruction of traditional electricity meters. Many countries are installing smart meters to enhance power sector reliability, decrease losses, improve the credit system, and boost energy efficiency. These cutting-edge meters enable automatic reading and offer features for monitoring, theft prevention, and energy management. They facilitate seamless interaction between electrical service providers (ESP) and consumers, making them a game-changer in the energy industry.

South Africa's experience with smart metering technology is a compelling case study. The country, which was losing an annual total of R20 billion at the national level and R15.2 billion at the municipal level due to electricity theft, saw a significant improvement in power sector efficiency at all levels with the implementation of smart meters (Kilian, 2017).

New Zealand's successful installation of almost 1.21 million smart meters, covering 70 per cent of residential connections, is a testament to the benefits of smart metering technology (Cormack, 2016). The Provincial Electricity Authority of Thailand also saw success with its smart meter project in Pattaya, which aimed to increase energy efficiency at the city level (Metering & Smart Energy International, 2017).

Singapore has already adopted smart metering technology to provide electricity for business consumers who purchase electricity from retailers (Bhunia, 2017). It was also mentioned that the Singapore Power Distribution Company will install smart meters for all electricity consumers, primarily households, across the country.

Several countries, including the USA, UK, France, Jamaica, Greenland, and Brazil are adopting smart meter technology. This technology aims to improve energy efficiency, reduce electricity theft (especially in Brazil, where theft rates are high), and ultimately increase revenue in the power sector (cited in Bimenyimana & Asemota, 2018). The major technologies include ZigBee, PLC, GPRS, DTSD5 modem, etc. (Hussain et al., 2016).

Some countries, such as Germany, have mandated adopting smart metering technology for the annual consumption of 6,000 KWH. However, this would exclude households and many small organisations with lower annual consumption (Knayer & Kryvinska, 2022).

Investments and financial incentives are crucial for strategic policy initiatives. Strategic policy initiatives and financial incentives have played a significant role in the adoption of smart meters in the US. The smart grid investment grant programme has been instrumental in driving this transformation, ensuring the widespread use of smart meters nationwide. The programme has facilitated the adoption of smart meters between different companies and within individual companies, leading to a substantial increase in smart meter deployment overall. The benefits of smart meters, such as improved outage management, operational efficiencies, and energy conservation, indicate that the programme has successfully encouraged the adoption of smart meter technology (Strong, 2017).

The introduction of smart meter technology by the European Distribution System Operators for Smart Grids (EDSO) in Italy helped to pinpoint where energy was being lost in the transmission system and how these losses could be minimised. Spain and France implemented smart meters without considering customer impact. In Finland, commercial factors and government legislation influenced smart meter deployment. In contrast, Sweden is the only country where smart metering was promoted solely due to consumer concerns, highlighting the growing importance of public opinion in shaping energy sector policies with government support (EPRS, 2015).

According to the UK House of Commons Public Accounts Committee, in uncompetitive energy markets, smart metering benefits energy suppliers more than consumers (UK Parliament, 2023). European consumer associations generally support smart metering but believe it should be optional for consumers and that they should not bear the installation costs. In some member states, distribution system operators (DSOs) deploying smart meters may pass on the costs to consumers through higher network tariffs (EPRS, 2015).

Installing smart meters benefits both utility companies and consumers. Utility companies can save money on meter reading costs and reduce billing errors, while households benefit from a more reliable grid and lower energy bills. However, because the benefits are not evenly distributed, the question arises who will bear the cost, or how can the costs of installing smart meters be shared between utilities and households? It might not appeal to non-compliant consumers or those not facing any issues, and some may not find the benefits worthwhile. To what extent are households or other consumer categories willing to pay installation costs? What factors affect their adoption decision? The study explores all these questions.

3. METHODOLOGICAL FRAMEWORK

3.1. Introduction

We used a mixed-method approach to conduct this study, which involved leveraging existing data and gathering both quantitative and qualitative data. This method provides significant value in that it involves comprehensive data collection, evidence generation, and facilitating the cross-validation of information. Importantly, it supports data triangulation (Fitzpatrick et al., 2011). The underlying approach followed the steps given below.

- Review and analysis of secondary data
- Primary data collection
    - Field visits
    - Key informant interviews (KIIs)
    - Cross-sectional questionnaire-based surveys

A desk review or secondary data analysis involves systematically assessing documents, reports, and data pertinent to a specific subject or project without conducting direct fieldwork. In our case, the aim was to gather insights, gauge the efficacy of smart meters, and identify the strengths and weaknesses of this technology for the electricity system in Pakistan. We reviewed published documents for this study and visited NEPRA and DISCOs' (e.g., IESCO, LESCO, MEPCO etc.) websites.

3.2. Understanding Billing Process

For the first objective, we employed a qualitative data analysis approach. This involved organising the descriptive data gathered from key informant interviews (KIIs), random field visits, and personal observations to understand how meter reading is conducted, registered, and transferred to the head office for final billing. By identifying patterns and themes within the textual data, we tried to understand the process and issues involved, even those that are not easily quantifiable.

For this objective, meticulous in-depth interviews with the staff of three DISCOs companies, namely IESCO, LESCO, and SEPCO were conducted. The interviewees included officers in the head office, regional offices, field officers (SDOs), meter readers, and their supervisors. To ensure the robustness of the findings, we also interviewed energy sector experts and NEPRA officials.

The purpose of conducting KIIs was to gather first-hand knowledge about the billing process. These interviewees provided insight into the process and the challenges faced.

For field visits, the dates of meter readers' visits to different areas were collected from the DISCO staff, and/or from consumers. Visits to households with utility staff and without staff on these dates were conducted.

3.3. Cost of Smart (Automated) Metering Infrastructure

The methodology for comparing the cost of AMI to a manual billing system involves the following steps:

- Visits to various smart meter companies/vendors located in Lahore to gauge the costs of various types of smart meters.
- Interviews with multiple technical experts to comprehend the intricacies and expenses associated with AMI at different stages.
- Interviews with relevant professionals at the two utilities, that is, LESCO and IESCO.
- A review of smart meter studies from other countries and the IESCO smart meter project report.

Based on the information collected, the cost per connection was estimated.

- For comparison, the cost of the manual billing system was also estimated based on primary data for various heads involved in the process. This information was collected from three DISCOs, namely Sukkur Electric Power Company (SEPCO), LESCO, and IESCO head offices/ relevant staff.

3.4. Willingness to Switch and Pay for the Smart (automated) Metering Infrastructure

A comprehensive survey was conducted to gauge consumers' willingness to transition from traditional to smart meters and their preparedness to finance this switch. The survey was structured around a detailed questionnaire, provided as Annex A1.

3.4.1. Unit of Analysis

The survey covered three cross-sections, i.e., households, commercial consumers, and industrial (small and medium) consumers in Islamabad, Rawalpindi, Lahore, Faisalabad, Multan, and Sukkur. The sampling design is described in detail below.

The primary target was household (domestic) consumers. The second group targeted in the survey was commercial consumers — retailers and wholesalers. The third consumer category surveyed was small and medium enterprises, regardless of their economic sector.

3.4.2. Study Locale

It is important to mention that the original plan was to conduct research in areas under the jurisdiction of two DISCOs, i.e., IESCO (covering only Rawalpindi and Islamabad) and LESCO (covering only Lahore). However, during the fieldwork planning phase, it was decided to expand the scope to include additional DISCOs. Consequently, two cities, Rawalpindi and Islamabad, from IESCO, Lahore from LESCO, Faisalabad from FESCO, Multan from MEPCO, and Sukkur from SEPCO were selected for the study. The focus was explicitly on urban areas.

Reasons for selecting these utilities/ cities:

- LESCO and MEPCO were selected because donor-funded smart meter pilot projects had already been implemented in these DISCOs a few years ago. We wanted to assess whether these projects have impacted consumer behaviour in the surrounding areas.

- Similarly, we chose IESCO because it was actively installing smart meters in Rawalpindi at the time of our survey, making it a strategically relevant choice for our study.

- FESCO was chosen due to the significant presence of small and medium enterprises (SMEs) in Faisalabad to diversify the sample

- SEPCO (Sukkur) was chosen because it has the second-highest transmission and distribution losses among all DISCOs. We wanted to assess consumer behaviour in areas with high non-technical losses. Another reason was to get additional perspective from interior Sindh.

3.4.3. Sampling Method/Strategy

For data collection, we implemented a multi-stage cluster-random sampling design. Below is a detailed description of the sampling design.

- In the first stage, we selected five DISCOs using purposive sampling (based on the reasons mentioned in the previous section).
  - IESCO
  - LESCO
  - MEPCO
  - FESCO
  - SEPCO

- In the second stage, the cities were selected using purposive sampling. The purpose was to pick major urban-centric cities from the selected power DISCOs.

- In the third stage, we used purposive sampling to form three clusters (households) within selected cities from selected DISCOs. These clusters represented the cities' high, middle, and less-developed areas. We observed these areas' physical infrastructure and housing size to classify them into high, middle, and less-developed areas. High-end utility customers, or the rich, generally live in areas with developed physical infrastructure, and the average housing size is at least one kanal. We chose middle and underdeveloped areas within specified cities using the same criteria.

- Apart from households, commercial consumers (shops/businesses) were also selected from these three area clusters. The list of areas surveyed is provided in Annex A2.

- For SMEs, the area was not specified, but wherever these are located within cities, and willing to participate in the survey.

- The survey was conducted door-to-door for the household sector (domestic consumers). Before conducting the survey, the team informed the households about its objective. If a household refused to respond, the team asked the next household for permission. In the case of commercial entities and SMEs, the survey was contingent upon respondents' availability and willingness to participate.

3.4.4. Determination of Sample Size

The sample size was determined utilising the standard statistical formula for sample size calculation. Parameters included a 95 per cent confidence interval ($Z=1.96$), $\alpha=0.05$ (Type-I error), $\beta=0.20$ (Type-II error), and a power of 0.80 (i.e., $1-\beta$). An error margin of 5 per cent and a standard error of 0.5 were also considered.

With these inputs and the number of electricity consumers in the selected DISCOs of their respective cities, the sample size for this study was determined to be 2,000 households. Resultantly, these households were surveyed in the selected cities.

The sample size distribution by city is given below:

- Multan: 400
- Faisalabad: 400
- Islamabad & Rawalpindi: 500
- Lahore: 500
- Sukkur: 200
- SMEs were primarily targeted in Faisalabad.

The sample size in each city was further classified according to consumer categories, including domestic, commercial, and SMEs. Table 1 presents a detailed breakdown of the sample.

Table 4. Sample Size Distribution by Consumer Category and City

City Name	Domestic Consumers		Commercial Consumers		SMEs	
	Total	(%)	Total	(%)	Total	(%)
Islamabad	172	66.41	87	33.59	0	0.00
Rawalpindi	191	73.18	70	26.82	0	0.00
Lahore	389	77.96	104	20.84	6	1.20
Faisalabad	204	49.51	165	40.05	43	10.44
Multan	238	59.50	160	40.00	2	0.50
Sukkur	104	52.00	90	45.00	6	3.00

3.4.5. Questionnaire Design

A comprehensive questionnaire was developed to collect data from the target demographic. The questionnaire includes questions aligned with the research objectives, encompassing the respondents' knowledge about smart meters, inclination to replace traditional meters with smart meters, willingness to pay, challenges encountered by consumers relating to electricity billing, cost, consumption, etc. Furthermore, questions relating to consumer income, education, occupation, etc., have also been included.

A survey was conducted using Survey CTO, the latest and widely used digital tool. It is user-friendly and provides tools to monitor data collection, ensuring the quality of fieldwork.

3.4.6. Techniques for Data Analysis

Cross-tabulation and data visualisation techniques were used to analyse the survey data.

3.5. Impact of Smart (Automated) Metering Infrastructure

Our study's fourth objective is to assess the effectiveness of smart meters. We designed another survey, recognising the invaluable role of consumer feedback in shaping the future of smart meters. This survey was designed to gather insights into consumer experiences after installing smart meters.

Our approach involved conducting a targeted survey of electricity consumers with smart meters. The survey was structured to investigate four key areas:

- *Change in Consumer Behaviour:* demand management or reduction in electricity consumption and savings through regular electricity usage monitoring.

- *Billing Accuracy:* decrease in complaints related to over-billing or over-reading.

- *Supply Reliability:* less electricity tripping
- *Consumer Satisfaction:* willing to replace and pay for these meters in future.

A comprehensive survey of electricity consumers was conducted in Multan and Lahore, where smart meters were installed three to four years ago. It is noteworthy that IESCO commenced the installation of smart meters in Rawalpindi a few months before the survey. Given that the immediate impact of smart meters is not possible and their full functionality has yet to be achieved in IESCO, we opted for LESCO and MEPCO for sample selection, where pilot projects were implemented at least a year ago.

3.5.1. Unit of Analysis and Survey Location

For selecting the sample, the information about target groups was collected from LESCO and MEPCO head offices. We wanted to keep our focus on domestic consumers, commercial consumers, and SMEs. However, in Multan, these meters were installed (under the pilot project) at the agriculture premises as well. Therefore, this survey was conducted targeting these four consumer groups. It is important to highlight the limitations that it was difficult to trace all these consumers and all were not willing to respond.

3.5.2 Sampling Method/Design

As for the other survey, a multi-stage stratified/clustering sampling design was employed to conduct this survey. The design is outlined as follows:

We began by choosing two DISCOs, namely LESCO and MEPCO, using purposive sampling. The criteria for selection were stringent, focusing on the DISCOs where smart meters have been operational for at least one year, as confirmed by the DISCO officials. This careful approach ensured the validity of our survey.

In the second stage, Multan in MEPCO[3] and Lahore in LESCO (as in the survey to

[3] In MEPCO, tube well connections on the periphery of Multan city were also targeted.

gauge consumers' willingness to transition from traditional to smart meters and their preparedness to finance this switch) were chosen as the targeted urban centres. The two DISCOs provided the list of connections with smart meters. Notably, the list provided by MEPCO officials included numerous connections from suburban areas and agricultural tube well connections (at the periphery of Multan). The DISCOs furnished us with consumer addresses and names, while MEPCO exclusively provided the smart meter's status (active or not). LESCO did not give this information. On the other hand, the lists provided by the DISCOs lacked the classification of connection types, particularly by MEPCO.

Owing to the lack of clarity regarding consumer categories in the lists provided, a random sample of 800 connections was selected, 400 from each DISCO. However, during the survey, the team tried to ensure that three main consumer categories (domestic, commercial, and SMEs) were covered.

A detailed description of the sample is given in Table 5.

Table 5. Sample Size Distribution by City and Consumer Category

City Name	Domestic Consumers		Commercial Consumers		Industrial/SMEs Consumers		Farmers	
	Total	(%)	Total	(%)	Total	(%)	Total	%
Lahore	307	76.75	71	17.75	22	5.50	0	0.00
Multan	30	7.44	167	41.44	47	11.66	159	39.45

3.5.3. Questionnaire Design

A comprehensive questionnaire was developed to collect data from the target demographic (consumers with smart meters). The questionnaire is designed to address the research objectives by including questions related to the effectiveness of smart meters and participants' satisfaction with the adoption of new technology. In addition, the questionnaire includes questions about consumer income, education, occupation, and other relevant demographic information. The survey was conducted using Survey CTO.

3.5.4. Methodology for Survey Data Analysis

In addition to cross-tabulations and data visualisations, regression analysis was also employed to ascertain the percentage of savings in consumer electricity bills. This comprehensive analysis factored in the impact of improved billing, regular monitoring of meter readings, and enhanced consumer knowledge regarding electricity slabs and rates resulting from implementing smart meters. The regression equation estimated is specified as follows:

$$logElectricity\ Bills_i = \alpha_i + \beta_1 \log Slabs\ Knowledge_i + \beta_2 \log billing\ improvement_i + \beta_3 \log Metre\ Monitoring_i + \mu_{i,t} \ldots\ldots\ldots\ldots (1)$$

Electricity bills were quantified in electricity units and billing amounts in PKR. Two separate regressions were estimated for electricity bills in units (kWh) and billing amount (PKR). The independent variables are defined as:

Meter Reading: Designated as one if regular meter monitoring is performed after the deployment of smart meters; otherwise, assigned a value of zero.

Knowledge of Electricity Tariffs Rates/ Slabs: Assigned a value of one if comprehension of electricity tariff enhances after installing smart meters, otherwise, attributed a value of zero.

Billing Improvement: A key variable affecting consumer electricity bills and a significant factor in our analysis, is denoted as one if there are fewer or no complaints about electricity billing after the installation of smart meters; otherwise, it is zero.

3.5.5. Impact on Utility Revenues

Data was also collected from two utility providers to evaluate the efficacy of smart meters from the utility standpoint. The analysis encompassed the impact of technology on reducing instances of theft and enhancing revenue recovery. The relevant data was procured from DISCOs through official requests and personal visits to these two DISCOs.

3.6. Determination of Payback Period

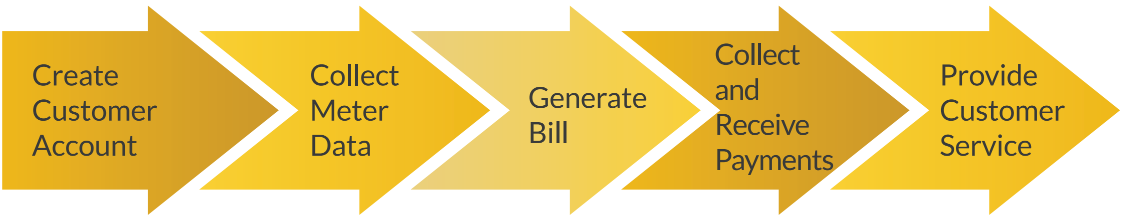
The information on consumer savings (Section 3.5.4) was then compared with the cost of smart meters (Section 3.3) to determine the payback period for consumers who invest in this technology. Based on this comprehensive calculation, the study recommends smart meter installation across all DISCOs.

4. MANUAL ELECTRICITY BILLING SYSTEM IN PAKISTAN

4.1. Meter to Cash

The commercial procedures implemented by electricity DISCOs are integral to facilitating the complete "meter-to-cash" process. The procedures encompass essential functions such as precise meter reading, accurate billing, and efficient revenue collection. The efficacy of these procedures is essential to ensure a smooth and dependable energy supply to all customers at the right rates.

Figure 2. Meter to Cash



In Pakistan, the public sector comprises ten DISCOs responsible for managing billing for an estimated 34.7 million consumers. Additionally, the private sector is represented by K-Electric, which oversees billing for approximately 3.6 million customers across diverse sectors.

Table 6. DISCO-Wise Number of Consumers (Millions)

DISCO	PESCO	TESCO	IESCO	GEPCO	LESCO	FESCO	MEPCO	HESCO	SEPCO	QESCO
Number of Consumers	4.2	0.4	3.7	4.4	6.2	5.1	7.9	1.2	0.8	0.7

Source: NEPRA (2023b).

For convenience, each DISCO is segmented into multiple general and specific MDI[4] batches, the quantity of which is contingent upon the customer base. For instance, IESCO organises its 3.7 million customers into 15 general and 4 specific MDI batches to facilitate the meter-to-cash process[5].

The meter reading for the cash collection process for all DISCOs involves several steps, as illustrated in Figure 3. The Customer Services Directorate (CSD) in each DISCO creates a schedule for meter reading and billing at the start of a billing month for each subdivision. This whole process has to be completed in eight days. On the eighth day, bills are distributed.[6] The customers must pay the bill within ten days, that is, by the 18th day of the billing month.

The initial part of the process, from taking the meter reading to collecting the payment, is currently done manually. This involves:

1. Requesting meter reading
2. Recording (uploading or sending) the reading (punching the meter reading of each consumer and its screen snapshot) from smartphones to the subdivision computer operated by the meter reading supervisor.
3. Manually inputting the results into the billing system CIS (customer information systems)[7] by the meter reading supervisor (or subdivision officer).

The data files are created per batch and subdivision. Once the meter reading data is recorded and validated in the subdivision office, the CIS batch-wise sends meter reading data files to the revenue Officer and subdivisional officer.

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[4] Maximum Demand Indicator.

[5] IESCO is divided into six circles, 20 divisions, and 110 subdivisions.

[6] During the night-time, all bills of that batch shall be printed. The next morning the Revenue Officer shall collect their bills and distribute them via the subdivision officer and the meter readers to the customers.

[7] CIS is a web-based billing, invoicing, payment, and customer service & management system designed for use by suppliers. In Pakistan, CIS is centralised information system at PITC, Lahore. The CIS system processes the meter reading and generates the bills.

All meter readers upload data to the subdivision computer at the same time, and the batch is completed. After all the required checks and corrections in the wrong readings, all subdivisions send the data to the revenue office in DISCO headquarters for onward transmission to the CIS system, which can only process a complete batch and not parts of it.

The CIS system processes the meter reading data and generates the bills. In other words, the centralised CIS system only partially supports this process. Recording units, their validation, and corrections are done manually.

The CIS system can only process a complete batch and not parts of it. According to DISCO officials, bills whose data fails the plausibility check, are not disseminated; the meter reader and the subdivision officer must verify the data. If inaccuracies are identified, the bill will be manually rectified to uphold precision. Conversely, if the meter reading data is confirmed as accurate, the bill will be distributed to the customer, thereby upholding the trust and integrity of the billing process.

Box 4. Meter Reading in Pakistan

Frequency and Personnel

- Meter reading is taken monthly for all consumers to accurately record their energy consumption during a billing cycle.
- Dedicated personnel are assigned based on consumer load:
  - General supply/general services (up to 20 kW): Meter readers
  - Industrial (20 kW - 40 kW): SDO/AM (Operations)
  - Commercial/agriculture tube well (up to 500 kW): XEN/DM (Operations)

- Consumers with load above 500 kW: Superintending engineer/manager (Operations)

Reading Methods

- Mobile Snapshots/handheld units - the primary methods used to capture accurate and tamper-proof meter readings.
- Manual recording - this method is used as a backup or in situations where electronic devices are not available.

Alternate Methods

- In exceptional circumstances (e.g., force majeure), consumers can provide meter reading snapshots for accurate billing.
- DISCO may issue a provisional bill based on average consumption if meter reading is not possible.

Percentage Checking

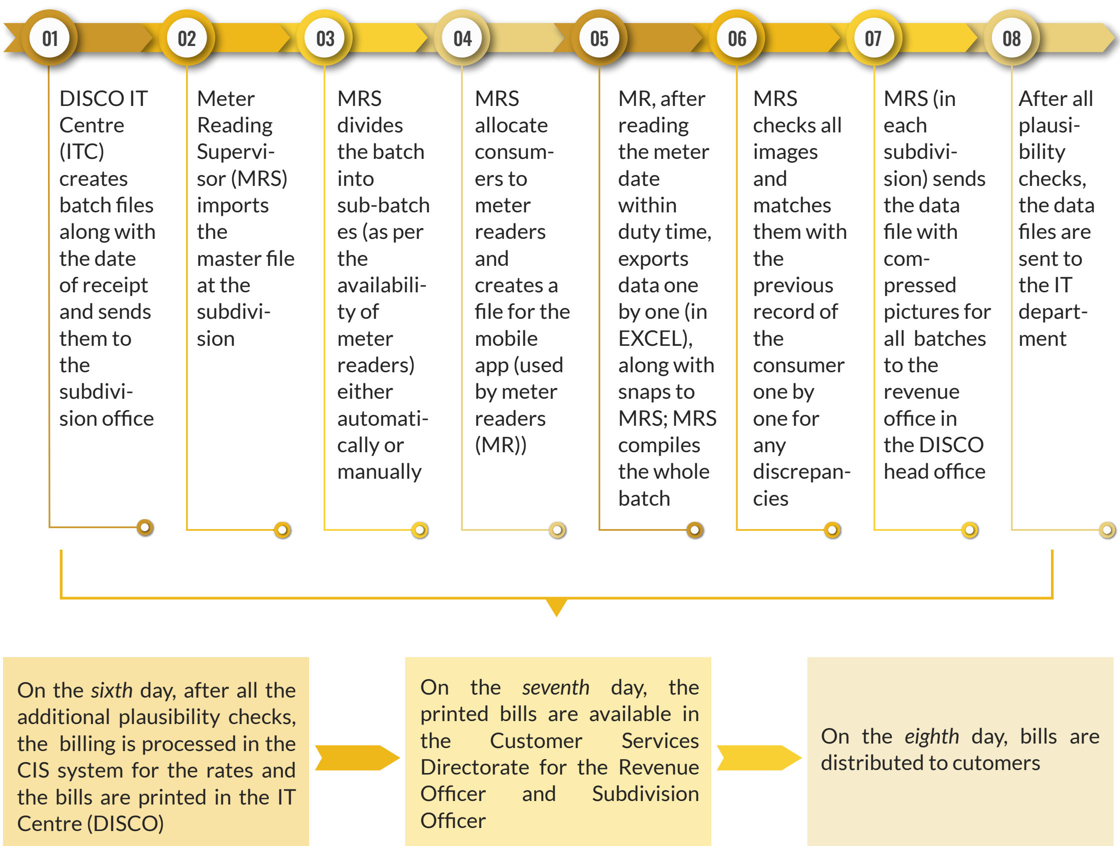
- Percentage checks are conducted on recorded meter readings to ensure accuracy and identify potential errors. The frequency of checks varies based on consumer type and load.
  - General supply/general services: 5%
  - Industrial (up to 20 kW load): 15%
  - Agriculture tube wells: 15%
  - Industrial/commercial/agriculture tube well (up to 40 kW): 2% (physical checks by SDO/AM(0))
  - Industrial/commercial/agriculture (above 40 kW - 500 kW): 10% (physical checks by XEN/DM(0))

- o Consumers with load above 500 kW: 15% (physical checks by SE/Manager(0))

Discrepancy Reporting and Action

- Discrepancies identified during checks are reported through established channels.
- Disciplinary action may be taken against personnel responsible for inaccurate meter readings.

Figure 3. Manual Billing Process



4.2. Manual Billing Process - Anomalies

Based on KIIs, field visits, and personal observation, the manual billing process in Pakistan exhibits the following anomalies. Information has been collected from IESCO, LESCO, and SEPCO for this particular objective.

- Meter-reading days are fixed. If a reading day is missed due to weather or any other unforeseen event, the consumer will get an approximate bill (based on the previous month's average); the reading will be done next month. Consequently, the consumer moves to higher slabs—this is common.

- Meter readers have a challenging job, reading an average of 300 to 500 meters daily. This workload increases the likelihood of errors, incorrect billing, and other malpractices. Reading 300 or more meters in a day is humanly impossible.

- The manual billing process allows for manual corrections if there are discrepancies in bill readings, unclear snaps, etc.

- Tempering in meter readings is easy with the involvement of a meter-reader/meter-reading supervisor.

- The job of supervisor or subdivision officer is also challenging. Validating thousands of readings in a day is not possible. The whole process must be completed in two days, which is impossible. For instance, if a subdivision has 10 meter readers, and each reads 300 meters daily, the supervisor has to validate 3000 readings in a day, increasing the likelihood of errors or ignorance.

- Moreover, it has been noticed that these officials (supervisor and meter reader) are also tasked with other functions, including customer service.

- Utility claim - they rotate meter readers, but not in actual practice.

- In consultation with various experts, it was revealed that not all are billing irregularities, many times other technical and non-technical losses are adjusted.
- In several subdivisions, the data is still being recorded in old-fashioned registers.

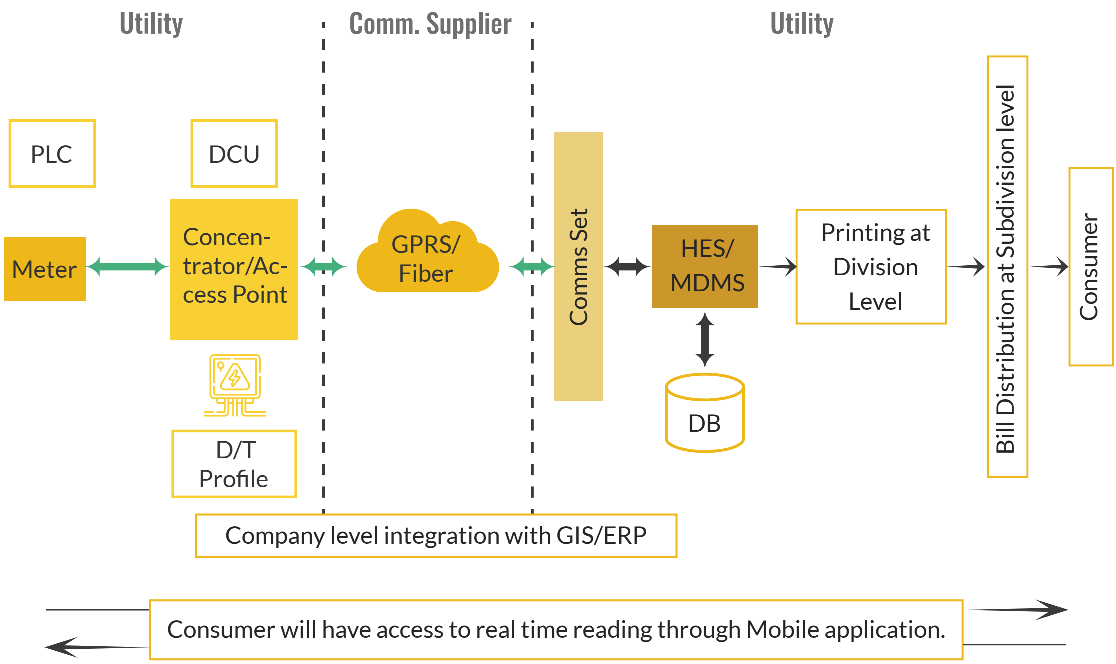
Mistakes/ irregularities are natural with the speed at which the whole process takes place.

The NEPRA inquiry report finds that billing months for about 10.7 million consumers are above 30 days (up to 40 days), which, per the utility staff briefing, is impossible. Certain officials have openly acknowledged that, due to their salary structure, instances of misconduct may be perceived as an inherent outcome.

The automatic meter reading (AMR) system, already installed in various pilot projects such as LESCO and MEPCO, or AMI, as under installation in IESCO, allows remote and AMR. These systems improve efficiency and reduce errors compared to the legacy manual billing system. Billing for AMR consumers with AMI is done remotely based on a schedule set by DISCO, eliminating the need for manual meter readings and associated potential errors.

4.3. Billing under Advanced Metering Infrastructure - IESCO

Figure 4. Billing System under Advanced Metering Infrastructure (AMI)



Source: Islamabad Electric Supply Company (IESCO).

IESCO is currently implementing state-of-the-art Advance Metering Infrastructure (AMI) meters for all tariffs. Over 900,000 meters will be installed by June 2026, initially in Rawalpindi City Circle, Rawalpindi Cantonment Circle, and Taxila (Division). The main and backup data centres have already been established at IESCO's head office and in Gujjar Khan, respectively, with a current capacity of 5 million connections.

The project is being carried out with financial assistance from the ADB. The new contract for the project was signed on September 3, 2022, and came into effect in January 2023.

Transitioning to the AMI system will eliminate power theft, improve billing accuracy, reduce power sector losses, manage power load-shedding, and address consumer complaints regarding incorrect or excessive billing. The system will allow consumers to monitor their electricity consumption through a mobile application and manage their bills more effectively, leading to significant cost reductions and operational improvements for IESCO.

According to IESCO officials, the system is 100 per cent accurate, and timely meter readings will significantly reduce meter reading costs. In the event of power theft, outages, power failures, or faulty meters, an automated alert will be sent to the data centre with instructions for the relevant SDO to rectify the issue promptly.

Continuous monitoring of load on meters and transformers from the data centre will also significantly reduce the failure rate of transformers and meters and operational costs for the organisation.

Box 5. Consumer Empowerment through the Mobile App

IESCO is rolling out smart meters in its jurisdiction, and other utilities like LESCO are following suit, specifically to replace traditional green meters with smart ones. However, despite the potential for a convenient mobile app for consumers, NEPRA's current policy does not allow it, as high-level utility officials have informed us.

Box 6. ADB Loan for AMI

The Ministry of Water and Power (MOWP) planned to install Advanced Metering Infrastructure (AMI) in major cities and industrial and commercial areas throughout the country. The installation requires USD

4.9 billion in investments, and the Asian Development Bank (ADB) was asked to finance a portion of this investment in 2013. The investment plan for the rollout was approved for IESCO and LESCO in the first phase.

In November 2016, ADB and GOP signed a USD 380 million loan agreement for external assistance. The project became effective in May 2017. IESCO and ADB signed an agreement for project implementation. USD 139.6 million was allocated to IESCO (and USD 232.2 million was allocated to LESCO). USD 8.2 million was allocated as interest payments to be divided between the two proportionately.

The loan proceeds were re-lent from the borrower to respective DISCOs under subsidiary loan agreements with the same repayment and grace periods as the respective loans, while the foreign exchange risk was to be borne by the borrower.

The following terms and conditions for the re-lending of the loan were agreed upon:

- 12 per cent per annum, including a re-lending interest of 5.2 per cent plus an early repayment charge (ERC) of 6.8 per cent, which shall be charged separately on the principal amount and interest amount.
- The maximum repayment period is 17 years, excluding the grace period of 3 years.
- The DISCO will bear all charges/fees, including commitment charges, if any, applicable by the GOP to the foreign lender pro-rate of all allocations made to them, in addition to the amounts of principal and interest.

The project was delayed, and as a result, the government had to pay USD 1 million as commitment charges by 2018, which swelled to USD 2.2 million by 2021. The new contract with IESCO was signed in September 2022.

The new AMI System (IESCO) will include smart meters (PLC or GSM/GPRS) installed at the consumers' premises. These smart meters will share load profile data with the data centre at least once every hour. The system is designed to ensure a collection rate of 98 per cent within 24 hours and 100 per cent within 48 hours, allowing IESCO to bill its consumers on any specific day according to standard operating procedures. Human interventions will be eliminated in the AMI System and billing will be based on the data directly received in the data centre.

4.4. Cost of Manual Billing

The comprehensive expense for the legacy billing system, encompassing meter readers' salaries, mobile app outlays, fuel, and costs linked to meter damages, is in the range of PKR 60 to PKR 80 per consumer (monthly) (Table 7). IESCO has provided the per-consumer cost for its conventional billing system and AMI, but the detailed breakdown has not been disclosed. Conversely, the costs for LESCO and SEPCO were estimated based on fundamental data from various sources within the two DISCOs. Further specifics are outlined in Annex A5.

The detailed cost of the AMI system, comprising smart meters and the establishment of data centre facilities, is approximately PKR 28 per consumer for IESCO. Chapter 7 provides additional insights into AMI costing.

Table 7 shows that implementing AMI will substantially reduce the electricity billing cost per consumer, alongside other associated advantages, which will be discussed in Chapter 6.

Table 7. Electricity Billing Cost Per Consumer

DISCOs	Billing Cost Per Consumer (PKR)	AMI Cost Per Consumer (PKR)
IESCO	60	28
LESCO	80	-
SEPCO	70	-

5. CONSUMER WILLINGNESS TO PAY FOR SMART METERS

5.1. Introduction

The most critical challenge in installing smart meters with the AMI (prepaid or post-paid) in Pakistan is the availability of financial resources for developing an IT infrastructure at the DISCO level and a two-way communication system, importing, or manufacturing meters, vending points (for a prepaid metering system), etc.

The AMI project has been under implementation by the IESCO with the financial support of the Asian Development Bank (ADB). Several pilot projects have been successfully executed in the past, notably in the LESCO, Peshawar Electric Supply Company (PESCO), and MEPCO, with financial and technical support from external donors. However, this reliance on external assistance is not conducive to long-term sustainability. It, in fact, increases the financial burden for the consumers, as these loans have to be paid back along with interest.

Many countries are now transitioning to smart metering infrastructure to address inconsistencies, focusing on garnering financial support from consumers themselves. While smart meters offer numerous benefits to consumers and utility providers, their knowledge about these benefits and consequent acceptance among consumers remains uncertain. Likewise, their willingness to pay for this transition is also not certain.

A comprehensive consumer opinion survey was conducted to gauge consumers' willingness to transition from traditional to smart meters and their preparedness to finance this switch. The survey was conducted in person and gathered responses from 2,000 participants across five major cities, Rawalpindi, Islamabad, Lahore, Multan, Faisalabad, and Sukkur.

5.2. Survey Findings

5.2.1. Consumer Profile

Figure 5 to Figure 8 illustrates the profile of consumers surveyed by type, city, income, and education. Results in a tabular form are provided in Annex A5. In the overall sample of 2,000, 63.09 per cent were domestic consumers and the remaining were commercial and small and medium enterprises. Among the commercial consumers, 77 per cent were retailers, 17 per cent were wholesalers, and the remaining were SMEs. SMEs were specifically targeted in Faisalabad. More Information on the consumers surveyed is available in Annex 6.

Figure 5. Percentage Distribution of Consumers

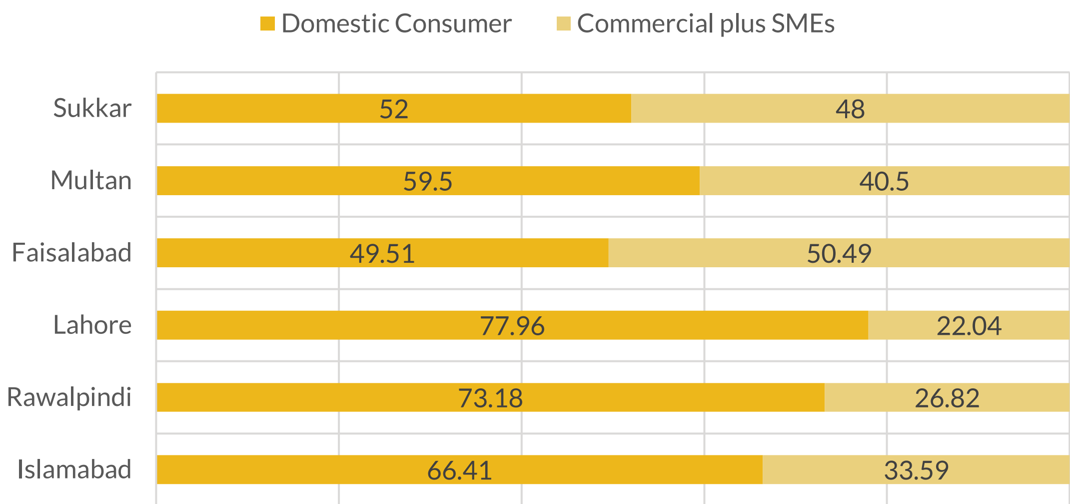


Figure 6. Commercial Consumers by Type (%)

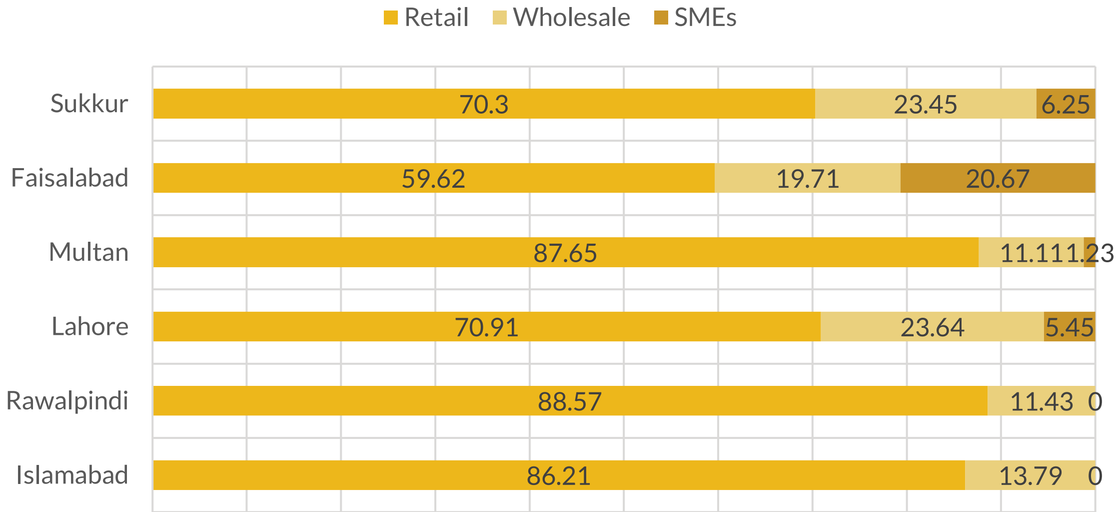


Figure 7. Domestic Consumers by Income Group (%)

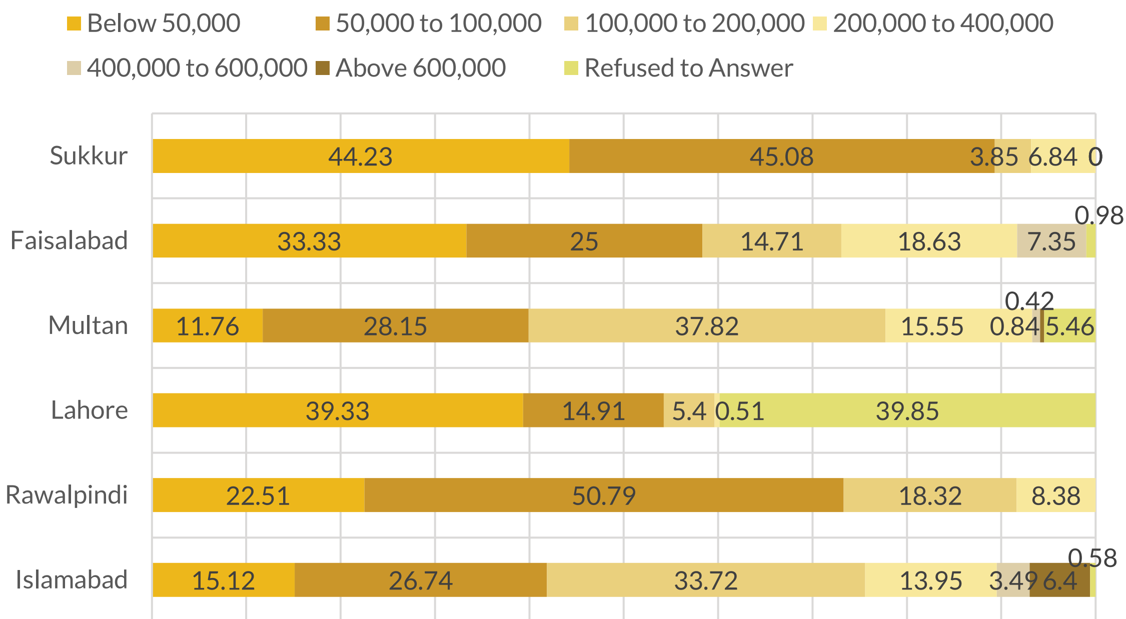
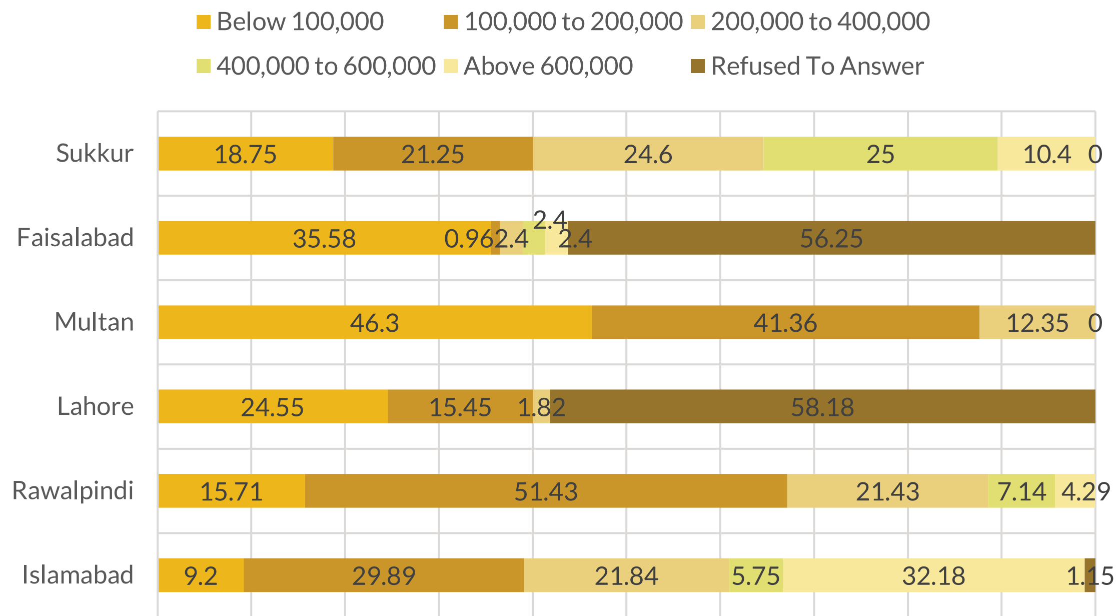


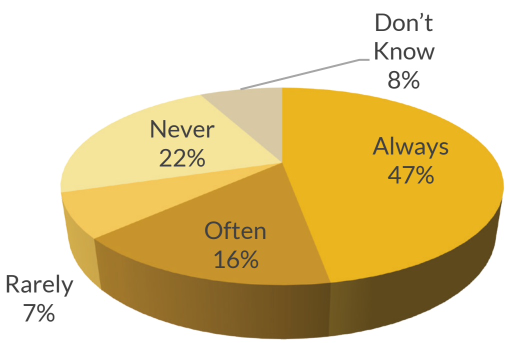
Figure 8. Commercial Consumers by Income Group (%)



5.3. Consumer Behaviour

The following figures depict general consumer behaviour regarding electricity consumption. These characteristics are detailed by city in Annex 5. The data from Sukkur was incomplete, resulting in a reduced sample size of 200. Only findings with 90 to 100 per cent of responses available are reported, ensuring that only valid information is included.

Figure 9. Per Cent of Consumers Noticing Their Consumption Slabs



- While 47 per cent of the surveyed individuals knew the electricity tariff slabs (Figure 9), only 17 per cent monitored meter readings regularly, with an additional 21 per cent doing so quite often (Figure 10).

Figure 10. Per Cent of Consumers Reading Meters

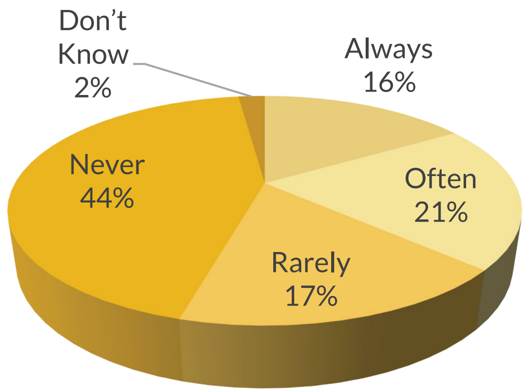
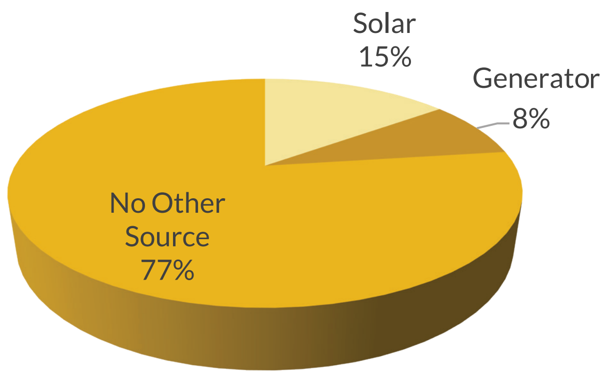
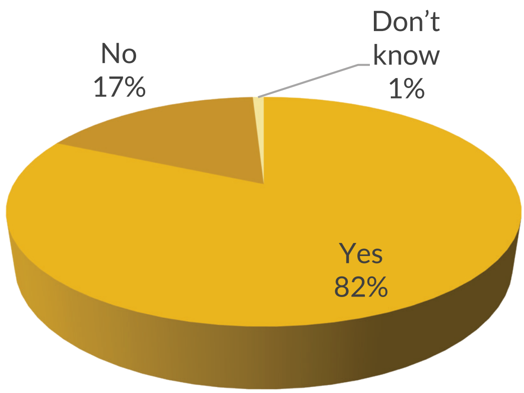


Figure 11. Per Cent of Respondents Relying on Electricity Sources Other Than Grid



- A substantial portion of individuals exclusively depended on grid electricity (Figure 11), and in their efforts to conserve energy, they utilised energy-efficient appliances (Figure 12).

Figure 12. Per Cent of Consumers Using Energy-Efficient Appliances



- A considerable proportion of the surveyed populace (76%) had encountered billing irregularities over the years (Figure 13). They frequently submitted complaints to the relevant authorities. However, merely 23 per cent of these grievances were redressed (Figure 14).

Figure 13. Per Cent of Consumers Experiencing Billing Irregularity

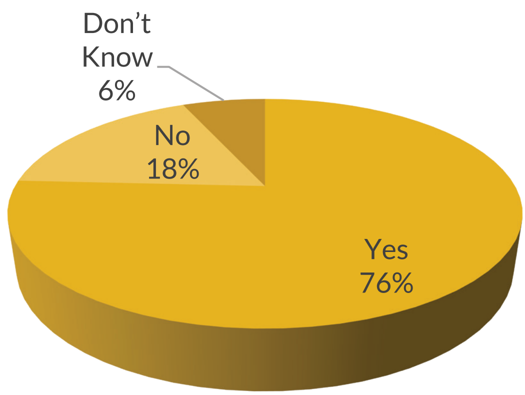


Figure 14. Per Cent of Complaints to Authorities and Problem Fixed

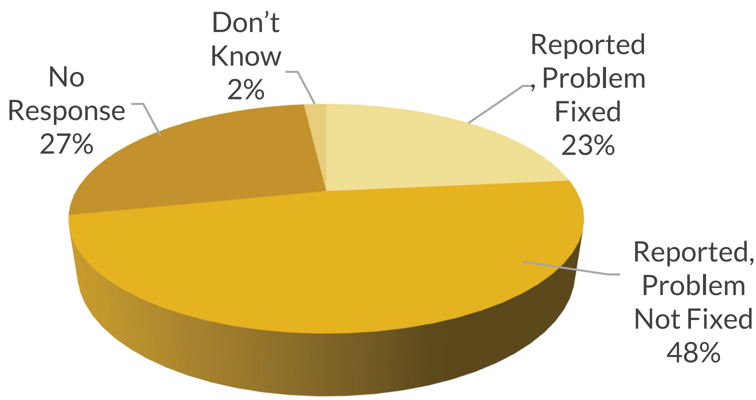


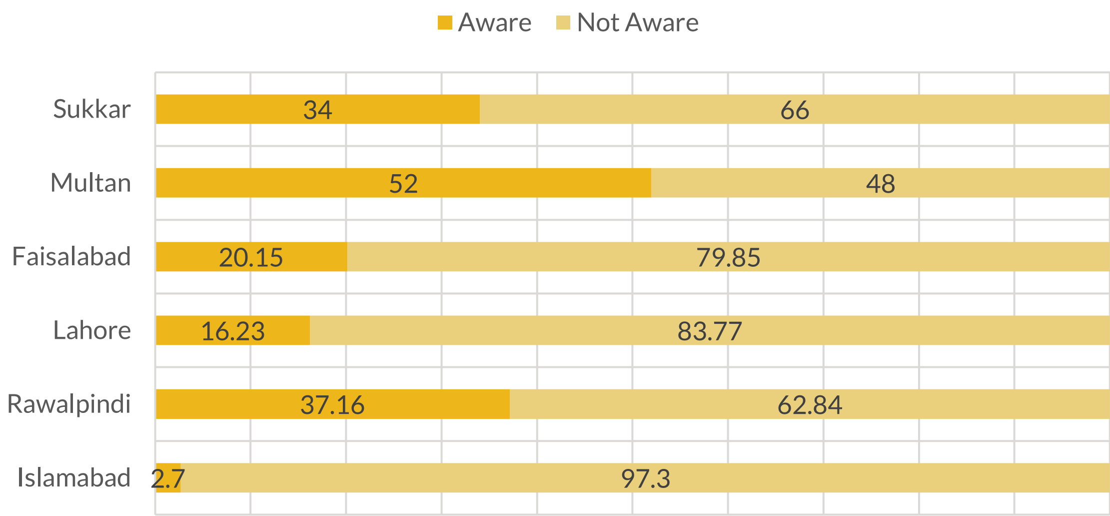
Table 8. Billing Irregularity (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Yes	64.86	73.95	77.15	90.53	67.25	75.81
No	34.75	26.05	16.83	5.34	14.75	17.64
Don't Know	0.39	0.00	6.01	4.13	18.00	6.55

5.4. Consumer Awareness of Smart Electricity Meters

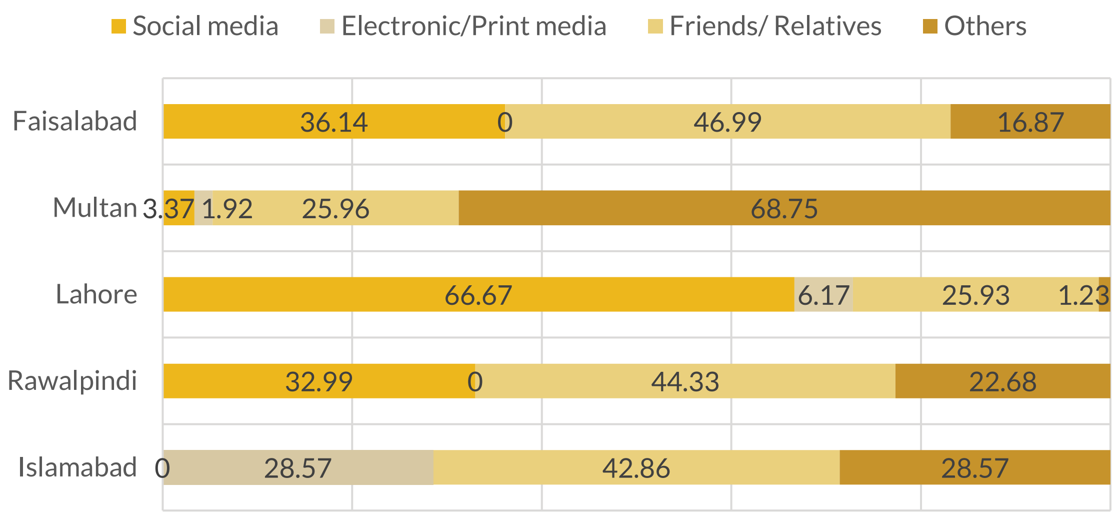
The primary objective of our study was not solely to gauge consumer willingness to transition to smart meters but also to cultivate awareness regarding the associated benefits. Consequently, before assessing their willingness, we first inquired whether consumers were acquainted with this technology. Surprisingly, approximately 73 per cent of the respondents were unaware of smart meters. Notably, the highest level of awareness, at 52 per cent, was observed in Multan among the surveyed consumers (see Figure 15 and Table A6.5 in Annex 6).

Figure 15. Consumer Awareness of Smart Meters (%)



Following a survey of individuals with prior knowledge of these meters, we inquired about the source of their knowledge. The findings are detailed in Figure 16 and Table A6.6 in Annex 6. Notably, Multan exhibited the highest level of awareness, prompting an investigation into the primary medium responsible for this. Contrary to expectations, Multan's predominant source of awareness was not social media, print, or electronic media but rather the utility provider itself. Specifically, MEPCO in Multan is disseminating awareness through billboards in prominent city areas. Additionally, the role of friends and relatives was significant in generating awareness overall.

Figure 16. Source of Awareness



The survey's primary aim was to ascertain consumer willingness to transition from traditional to smart meters and their inclination to bear the associated costs. Consequently, enumerators were tasked with first acquainting uninformed respondents with the concept of smart meters and their benefits before proceeding with the survey questionnaire.

5.5. Willingness to Replace Conventional Meters

Notably, approximately 79 per cent of the surveyed population demonstrated a willingness to exchange their traditional meters for smart meters (see Figure 17). Furthermore, following the provision of information, 74 per cent of respondents previously unaware of smart meters expressed a similar willingness to make the transition (see Figure 18). The information regarding consumer willingness to replace meters by income groups and consumer types is detailed in Annex 6.

Figure 17. Willingness to Replace Conventional Meters with Smart Meters (%)

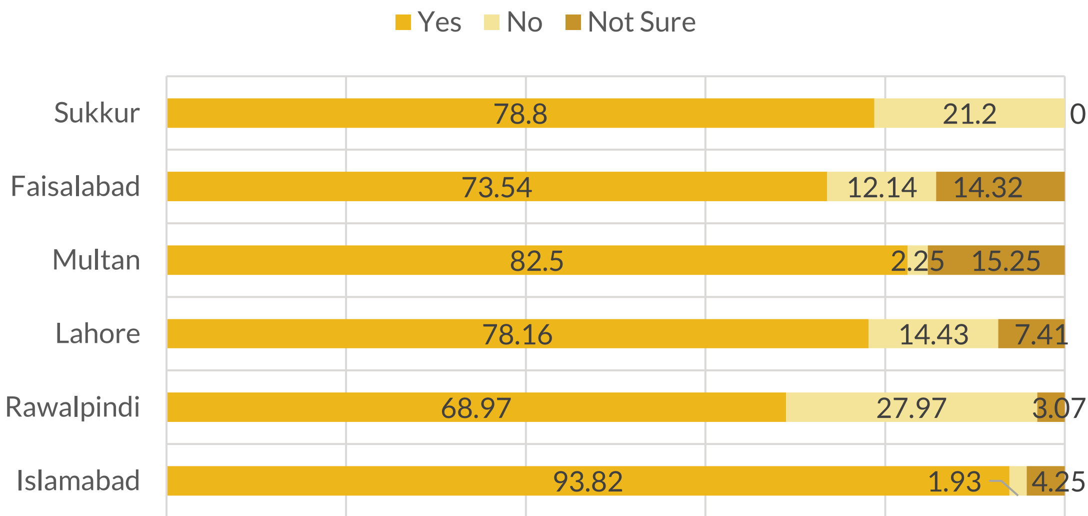


Figure 18. Willingness to Replace Among Those Who Were not Aware but Informed by the Enumerators

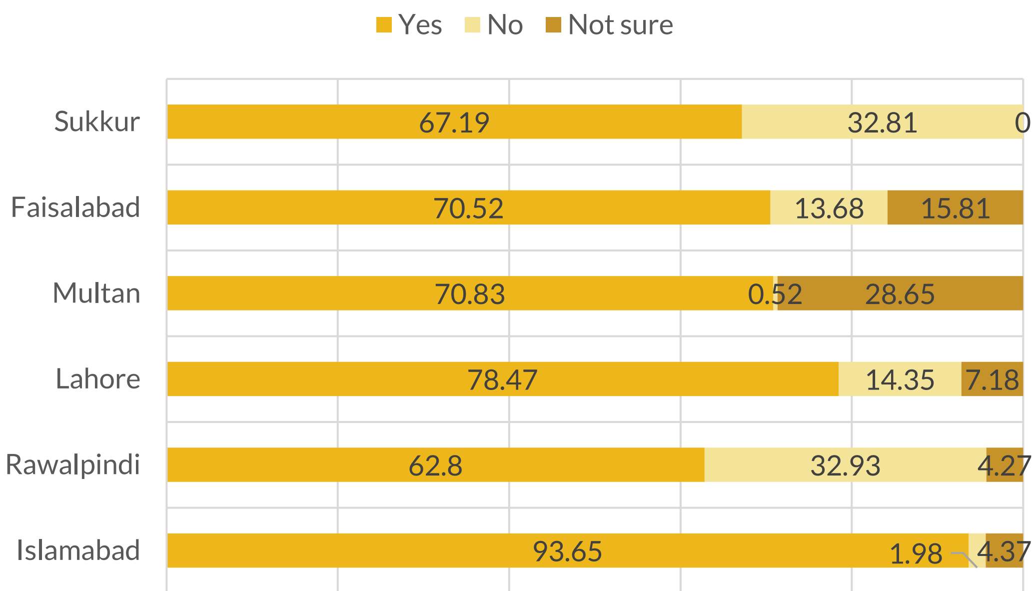


Table 9. Willingness to Replace Among Those Facing Billing Irregularities

Billing Irregularity →	Yes	No	Don't Know
Willingness to Replace ↓			
Yes	79.32	15.63	5.05
No	56.46	38.28	5.26
Not Sure	69.89	9.66	20.45

Table 10. Willingness to Replace Among Those Using Energy-Efficient Appliances

Energy Efficient Appliance use →	Yes	No	Don't know
Willingness to Replace ↓			
Yes	82.92	16.39	0.69
No	79.43	20.57	0.00
Not Sure	75.57	21.02	3.41

- About 79 per cent of consumers facing billing irregularities (irrespective of their consumer category) were willing to replace their conventional meters (Table 9).
- Likewise, of those who were savvy enough to use energy-efficient appliances to save energy bills, 82.9 per cent wanted to replace their meters with the new technology (Table 10).

As previously explained, notwithstanding the advantages attributed to smart metering technology, the foremost obstacle for utilities is the financial burden associated with its infrastructure. Even if said infrastructure is established through loans, as exemplified by IESCO's utilisation of ADB loans, the eventual repayment falls upon consumers through billing. In instances involving loans, the aggregate sum escalates significantly due to accrued interest and ancillary fees.

Consequently, our study advocates that consumers ought to assume direct responsibility for the transition cost, namely the expenditure on the installation of smart meters at their respective premises. Undoubtedly, such meters should be deemed consumer property, thereby warranting their financial obligation.

It is imperative to underscore that utility providers levy charges on consumers to replace meters in case of malfunction or damage within the extant manual billing framework. So why not for the smart meters' infrastructure (specifically smart meters) instead of loans?

IESCO consumers are now charged a meter rent of PKR 1,000 on their monthly electricity bills. Secondly, the tariff determinations will include new investments and financing costs. Again, it is essential to highlight that in Pakistan, there is a uniform tariff policy, and all DISCOs' financials are consolidated to determine a uniform tariff. In other words, if smart meters are installed in one DISCO, their impact will also affect consumers in other DISCOs.

Therefore, in the next section, we present our findings regarding consumers' willingness to pay for smart meters.

5.6. Willingness to Pay for the Transition

In general, consumers are willing to pay for smart meters. Among those seeking to replace conventional meters with smart meters, 30.5 per cent of domestic consumers are willing to cover 100 per cent of the smart meter's costs (Figure 19 and Table 11). Furthermore, consumers with an income exceeding PKR 200,000 are willing to bear 100% of the smart meter costs (Table 11).

Figure 19. Willingness to Pay by Consumer Category

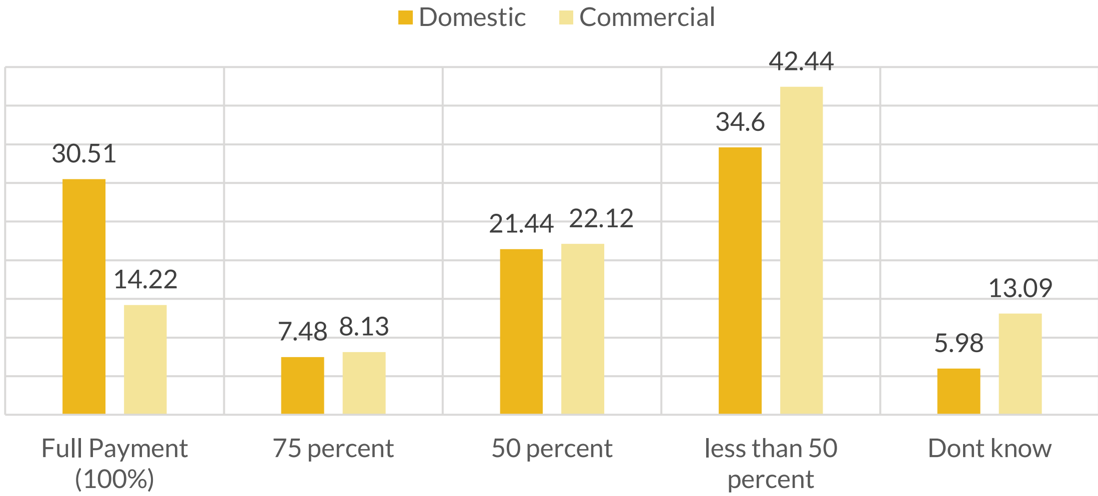


Table 11. Willingness to Pay (Domestic) by Income Groups (%)

Payment	Below PKR 50,000	PKR 50,000 to 100,000	PKR 100,000 to 200,000	PKR 200,000 to 400,000	PKR 400,000 to 600,000	Above PKR 600,000	No Answer	Total
Full (100%)	3.97	27.37	41.15	88.46	95.65	100.00	6.98	30.51
75%	7.14	5.11	14.35	3.85	0.00	0.00	6.98	7.48
50%	26.19	24.09	33.01	0.00	0.00	0.00	10.85	21.44
Less than 50%	58.73	37.59	3.83	0.00	0.00	0.00	68.22	34.60
Not Sure	3.97	5.84	7.66	7.69	4.35	0.00	6.98	5.98

Notably, 26 per cent of individuals with incomes below PKR 50,000, expressed a willingness to cover 50 per cent of the expenses associated with smart meter installation. The highest percentage of individuals willing to cover the entire cost (100%) was observed in Faisalabad, followed by Islamabad and Rawalpindi.

Figure 20. Willingness to Pay by City (%)

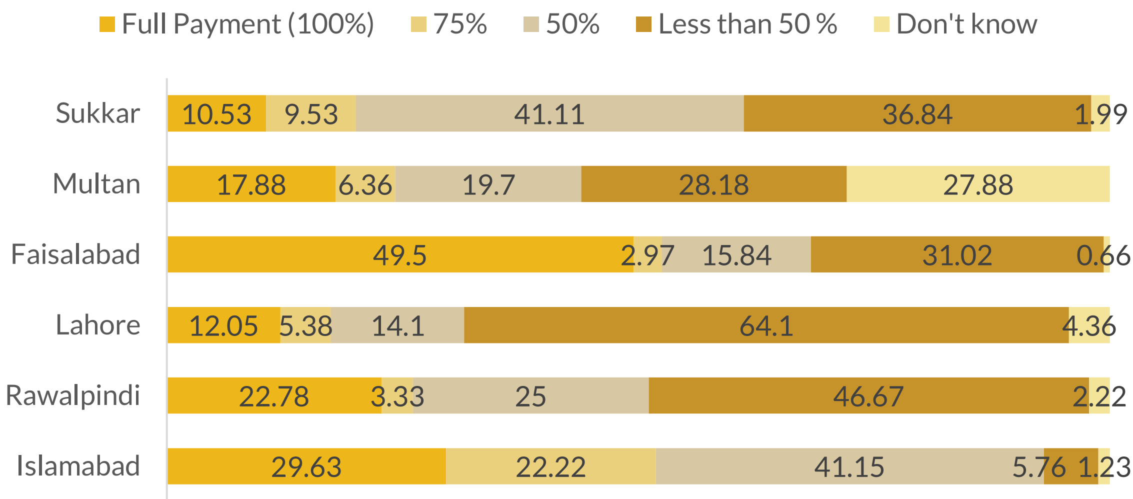
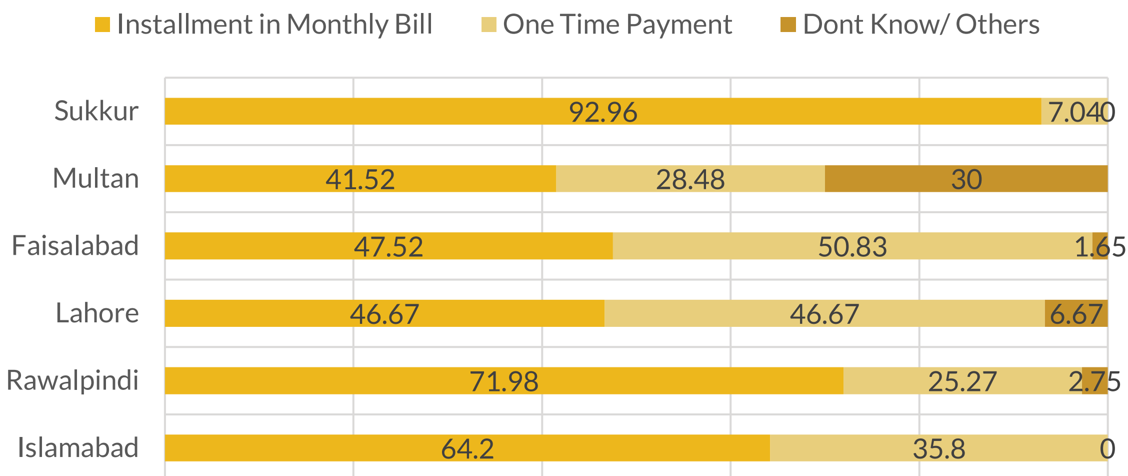


Figure 21. Willingness to Pay – Payment Mode (%)

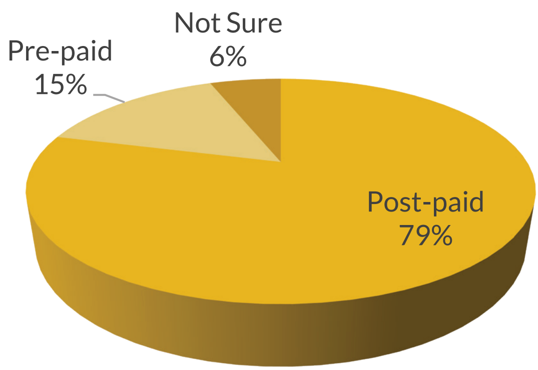


In all cities except Faisalabad, the majority of consumers expressed a preference for paying in monthly instalments. This trend is attributed to the pervasive impact of inflationary pressures on the populace. Consumers are grappling with heightened stress from escalating electricity tariffs, compelling them to curtail their expenditures.

5.7. Prepaid vs Post Paid Smart Meters

In Pakistan, IESCO (currently implementing) and previous pilot (smart metering) initiatives exclusively implemented only a postpaid smart metering system. In contrast, a prepaid system gives consumers a sophisticated payment alternative similar to mobile phones. With this metering option, consumers can procure electricity units in advance, with enhanced control over their electricity consumption. Furthermore, prepaid metering offers an efficient, streamlined approach to revenue collection. This research also sought to ascertain consumer perceptions of pay-as-you-go or prepaid meters.

Figure 22. Consumer Preference for Prepaid Smart Meters (%)



The survey data shows that the majority was against implementing a prepaid metering system, as depicted in Figure 22. Upon further probe, it was revealed that the primary concern revolved around the potential scenario of the card balance being depleted at night and the operational implications of the prepaid system.

Additionally, it is pertinent to emphasise that, as per IESCO sources, an application has been submitted to NEPRA for the establishment of prepaid metering rules and regulations. However, the application is currently pending with NEPRA.

6. IMPACT OF SMART METERS

6.1. Preface

USAID implemented a pilot project to improve the power sector by installing an AMI system in selected areas under the administration of PESCO, MEPCO, and Hyderabad Electric Supply Company (HESCO) between FY2017 and FY2020. This project consisted of three components: installing smart meters (AMR), installing headend applications, and developing a web-based portal for monitoring the installed smart meters. The system used smart meters and related hardware and software to collect data and integrate the AMI. The goal was to create an automated metering system to reduce losses, improve load management, provide real-time customer load profiles, and enhance billing quality and revenue.

The AMI headend systems were installed at the PITC Data Centre (centralised), Lahore, providing DISCOs' field users with remote access through secure private physical and logical VPN links. DISCOs were granted access to a meter data repository via web-based applications for billing and analysis. Additionally, subdivisions, divisions, and revenue offices were connected over the IP cloud to facilitate day-to-day operational and commercial activities. Smart meters were deployed in specific areas. To assess their effectiveness, the present study aimed to target areas where smart meters had been operational for at least one year.

As information about specific locations/consumers where these meters were installed is not publicly accessible, we sought details from the three utilities involved (LESCO, MEPCO, and PESCO). Subsequently, we officially obtained the requisite information from MEPCO, while LESCO staff furnished us with the list of areas but did not provide information about whether these meters were still active. MEPCO proactively notified us about the non-functional meters. Therefore, in MEPCO, we targeted only those addresses where meters were still active during the survey. Unfortunately, we did not receive a response from PESCO.

We conducted a survey of 800 consumers with smart meters evenly distributed between the MEPCO and LESCO utilities. It is noteworthy that only three-phase meters were replaced under the USAID project.

Following the implementation of the AMI rollout, DISCOs achieved a net benefit of USD 175 million in energy sales savings and improved revenue collection. This initiative also reduced technical losses, enhanced system reliability, improved customer service, decreased billing complaints, increased operational efficiency, demand side-load management, reduced operating costs, and complete automation of electricity metering and billing operations (USAID, 2020).

6.2. Consumer Satisfaction with Smart Meters

In our sample, 57 per cent of respondents expressed satisfaction with smart meters. The satisfaction level was significantly high in Multan at 86 per cent, compared to 27 per cent in Lahore (see Figure 23 and Annex A7). Subsequently, we investigated the reasons for dissatisfaction among those surveyed.

In Lahore, in particular, the reasons other than those listed in Table 12 for being unsatisfied included:

- Consumers were not informed about smart meters' benefits before their installation.
- Their consent was also not taken.
- Most meters experience malfunctions after a certain period, so people opt for reverting to the conventional system, which is relatively cheaper. Given that these consumers lacked awareness of the advantages of smart meters, they understandably hesitated to cover the associated costs.

Figure 23. Consumer Satisfaction with Smart Meters (%)

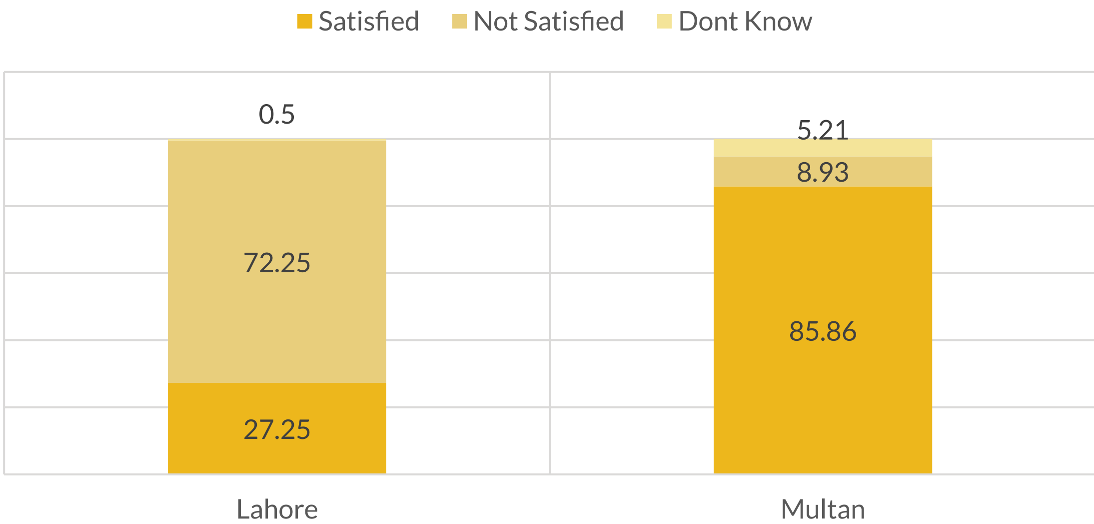


Table 12. Reasons for Being Dissatisfied with Smart Meters (%)

Reasons – Dissatisfaction	Lahore	Multan	Total
Not User-friendly	4.12	54.39	12.36
Technical Issues	20.96	8.77	18.97
Billing Problem	73.54	5.26	62.36
Others	1.37	31.58	6.32

6.3. Impact of Smart Meters on Consumers

6.3.1. Reduction in Billing Issues

Our first question for respondents satisfied with smart meters was about their experience regarding the reduction of billing-related issues, such as over-billing. In Lahore, 100 per cent of participants reported a decrease in billing issues, while in Multan, the figure was 97%. However, among those who were unsatisfied, billing issues persisted in Lahore. In Multan, many users found the smart meters to be user-unfriendly, and the majority encountered technical problems.

Nevertheless, this is natural as literature also suggests that in the initial stages, smart meter technology is often complicated and not user-friendly. Many users struggled to grasp their total energy consumption, which hampered their ability to make informed decisions about their energy use (Adams et al., 2021). Notably, some satisfied users in Multan chose to replace their smart meters with new ones at their own expense.

Figure 24. Reduction in Billing Issues

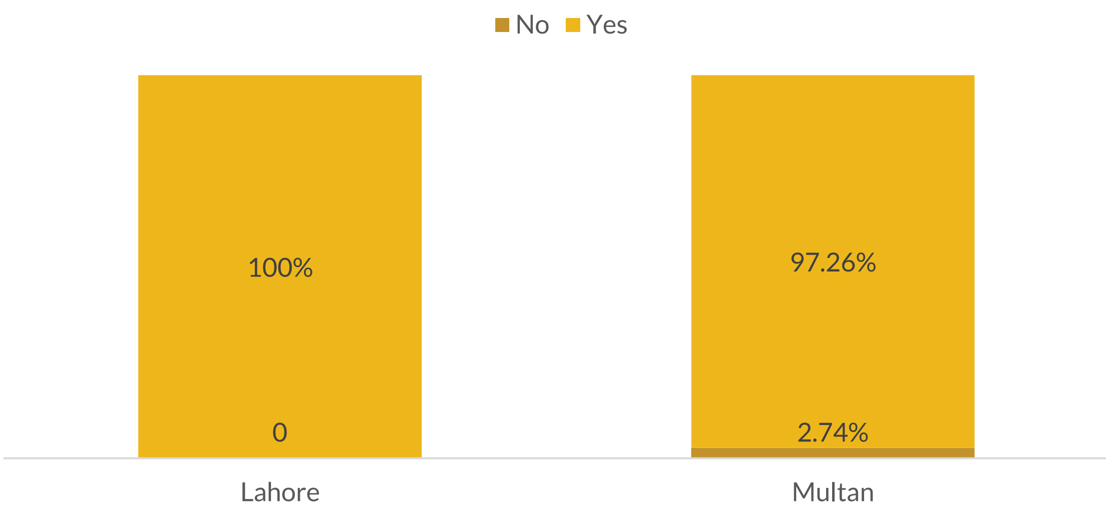
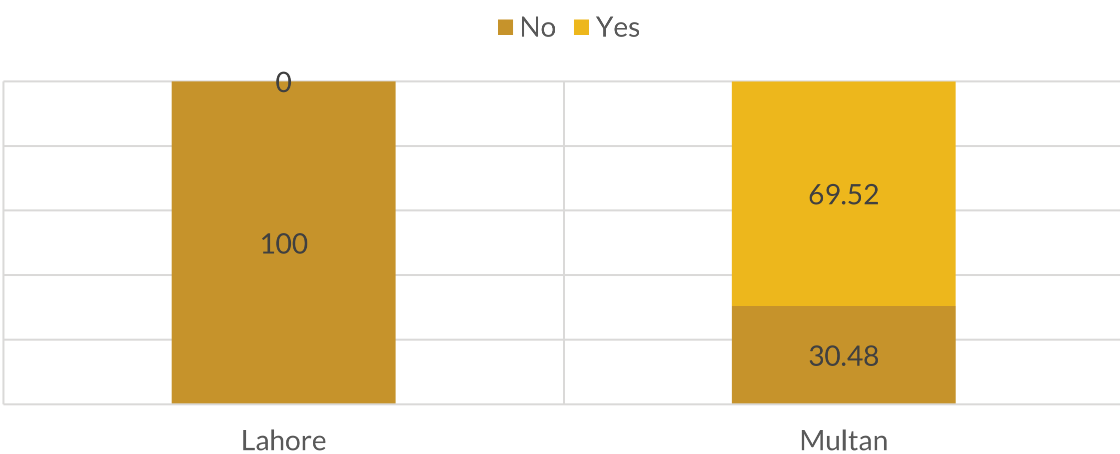


Figure 25. Reduction in Electricity Bills (%)



No significant difference was found in the meter reading habits. When asked why they were not so particular about regularly reading their consumed units, they were unaware of how they could manage their bills through regular monitoring. Secondly, a mobile application to regularly monitor consumption patterns was not provided.

6.3.2. Demand Management

In Multan, the implementation of smart meters has resulted in a notable decrease in electricity consumption, reflecting smart meters as an effective demand management strategy (Figure 26). Conversely, the impact in Lahore has been limited, attributable to the reasons previously outlined. On average, 79 per cent of consumers experienced reduced electricity usage, with a decrease ranging from 5 per cent to 10 per cent (see Table 13). Additionally, a mean analysis was conducted for both summer and winter, with the findings detailed in Tables 14 and 15. The findings highlight a significant change due to the adoption of smart meters.

Figure 26. Demand Management (%)

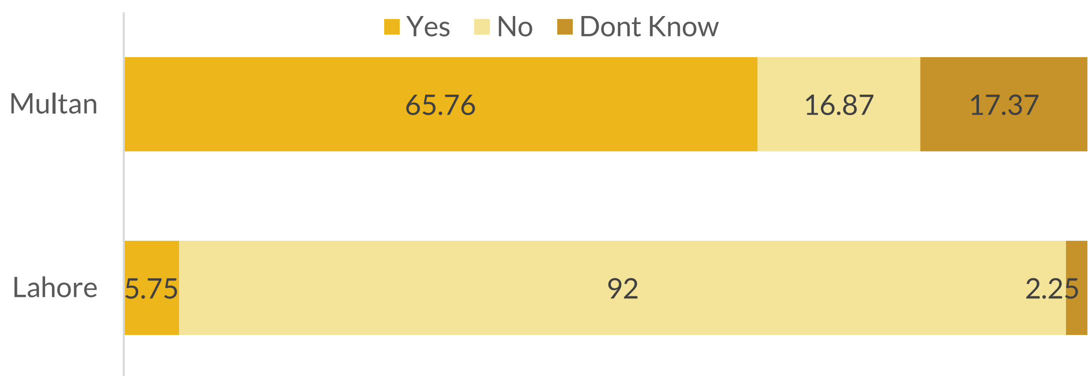


Table 13. Per Cent Reduction in Consumption (For Those Who Said "Yes")

	Lahore	Multan	Total
Less than 5%	0.00	10.94	10.07
5% to 10%	0.00	86.04	79.17
10% to 20%	43.48	3.02	6.25
20% to 30%	47.83	0.00	3.82
More than 30%	8.70	0.00	0.70

Table 14. Mean Analysis of Electricity Consumption During Summers (Units)

		After Smart Meter	Before Smart Meter	Mean Difference
Households	**Overall**	**242.26**	**268.56**	**-26.3*** (-2.95)**
	Lahore	190.23	197.68	-7.44** (-2.58)
	Multan	953.33	1,237.33	-284*** (-2.58)
Industry	**Overall**	**20,079.37**	**20,094.95**	**-15.57 (-0.02)**
	Lahore	2480.8	2,480.4	0.40 (0.004)
	Multan	39,633.33	39,666.67	-33.33 (-0.049)
Commercial	**Overall**	**6,462.33**	**7,801.77**	**-1339.44** (-2.57)**
	Lahore (only 4 value)	200.05	200.07	-0.02 (-0.002)
	Multan	7,536.70	17,323.90	-9787.19** (-2.56)
Agriculture	**Overall**	**2,611.42**	**3,257.14**	**-645.71** (-2.20)**

*Note: A simple t-test is used to check the statistical significance of the mean difference; t-stat is in parentheses () while *** p<0.01, ** p<0.05, * p<0.1*

Table 15. Mean Analysis of Electricity Consumption (Units) During Winters

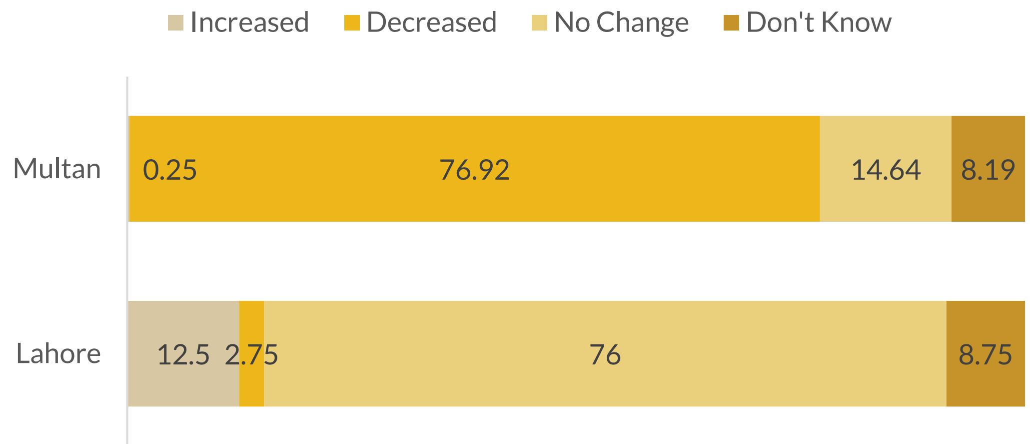
		After Smart Meter	Before Smart Meter	Mean Difference
Households	**Overall**	**179.89**	**217.42**	**-37.52** (-2.39)**
	Lahore	97.04	99.29	-2.24** (-2.08)
	Multan	1,200	1671.87	-471.87** (-2.62)
Industry	**Overall**	**3,797.36**	**4,997.36**	**-1200*** (-2.89)**
	Lahore	1,335	2525	-1190** (-1.95)
	Multan	6,533.33	7,744.44	-1211.11 (-2.04)
Commercial	**Overall**	**3,199.06**	**4,040.65**	**-841.58*** (-3.47)**
	Lahore (only 5 value)	141.4	144	-2.60 (-1.00)
	Multan	3,571.95	4,515.85	-943.90*** (-3.53)
Agriculture	**Overall**	**1,314.28**	**1,928.57**	**-645.71** (-2.20)**

*Note: A simple t-test was used to check the statistical significance of the mean difference. t-stats are in parentheses, while *** = p<0.01, ** = p<0.05, and * = p<0.1*

6.3.3. Impact on Grid Reliability

As illustrated in Figure 28, the percentage of electrical tripping in Multan significantly declined following the installation of smart meters. In short, more reliable electricity is supplied with smart meters.

Figure 27. Percentage of Electricity Tripping



Smart meters (SMs) have not achieved their intended effectiveness in Lahore (LESCO) from the consumer's perspective. A significant reason for this shortcoming is that this initiative failed to consider the occupants' attitudes, knowledge, opinions, and behaviours before its implementation.

However, in Multan (MEPCO), consumers had knowledge and prior consent for this transformation (Table 16). They realised its benefits through experience. Consequently, when the need arose, that is, when smart meters became defective. Instead of switching back to conventional meters, they replaced them with new smart AMR meters.

Table 16. Consumer Consent Before Smart Meter Installation (%)

	Lahore (LESCO)	Multan (MEPCO)	Total
Yes	0.00	83.13	41.72
No	100.00	6.45	53.05
Don't Know	0.00	10.42	5.23

It is essential to note that although DISCOs are in the process of installing smart meters, this implementation is currently selective – specifically for companies such as LESCO and MEPCO – while IESCO is deploying smart meters for all of its consumers. However, NEPRA has not yet authorised the development of a mobile application for consumers[8].

6.4. Impact on Utilities

To get the utilities' perspective, we asked both MEPCO and LESCO about the impact of smart meters on commercial performance.

- LESCO projected savings with smart (AMR) meters from FY2016-17 to FY2023-24 on three loss-making 11KV feeders (Ali Hajvari, Madina Town, and Sabzi Mandi) is PKR 960 million (Table 17).

Table 17. Savings with Smart Meters (AMR) - LESCO

11kV Feeders	Units Lost before AMR kWh	Units Lost after AMR kWh	Units Saved kWh (%)	Savings in PKR Billions (FY17 to FY2024)
Ali Hajvari	35,415,912	13,390,095	22,025,095	399.28
Madina Town	32,438,287	10,438,618	21,999,669	369.74
Sabzi Mandi	21,845,331	10,875,432	10,969,899	191.32
Total	89,699,530	34,704,145	54,995,385	**960.34**

- MEPCO estimated a saving of about PKR 2.2 billion in 11 months with 150,000 smart meters (Table 18).

[8] DISCO Sources.

Table 18. Saving for MEPCO After Converting 150,000 Conventional Meters to Smart Meters (AMR)

Billing Months (Feb. to Dec. 2021)	No. of AMR Consumers (Sample)	2020 (Pre AMR)	2021 (Post AMR)	Increase (+)/Decrease (-)	Growth Rate %
		Units Billed (kWh) (11 months)	Units Billed (kWh) (11 months)		
	A	B	C	D=(C-B)	E=(D/B*100)
Total	882	27,575,487	31,526,103	3,950,616	14.33
Savings with a 60% Growth Factor					8.60
Saving from 882 Meters in 11 Months (kWh-Units)					339,592
Per-Meter Savings in 11 Months (kWh-Units)					385
Per-Meter/Per-Month Savings (kWh-Units)					35
Savings on 150,000 Meters/Month (kWh-Units)					5,250,343
Savings on 150,000 Meters/Annum (kWh-Units)					63,004,117
Sale Rate Per kWh					34.29
Per-Annum Savings (Million PKR)					2,160

Next, we simulated the incremental revenue generated by implementing smart meters across ten DISCOs. Ten DISCOs have a consumer base of 34.684 million. If AMI with smart meters is implemented to cover 50% of this consumer base, and given a growth factor of 20%, our simulations suggest that the estimated savings will surpass PKR 95 billion in a year, based on an average sale rate of PKR 39.46 per kilowatt-hour (for FY2024).

6.5. Savings from Smart Meters for Consumers

Using survey data, we estimated Equation (1) (see Section 3.5.4) for both electricity bills and electricity consumption units as the dependent variable. Estimated regression results using electricity consumption units are reported in Annex 8.[9]

[9] Coefficients in a regression equation with electricity bills were less significant, therefore, not reported.

The analysis (using regression with electricity units) reveals that regular monitoring of meters or meter readings is associated with estimated savings of approximately 11 per cent through effective demand management. Furthermore, when consumers increase their understanding of tariff slabs and actively strive to remain within the lower slabs, they can achieve reductions of up to 25 per cent in their consumption units. In addition, addressing billing irregularities could lead to a reduction of 16 per cent in consumer bills based on the units consumed.

Based on the estimated coefficients, we conclude that consumers who use smart meters, along with increased awareness and empowerment, can achieve an average savings of up to 17 per cent in electricity consumption. The reductions in electricity usage resulting from implementing smart meters are detailed in Table 19 below.

Table 19. Savings in Electricity Units with Smart Metering System

	Meter Reading		Slabs		Overbilling	
	Consumption Units	Savings Units	Consumption Units	Savings Units	Consumption Units	Savings Units
Households	951.9074	104.709814	816.06	204.015	791.3889	118.7083
Industry	13,498.26	1,484.8086	7,824.071	1,956.018	12,758	1913.7
Commercial	5,089.44	559.8384	5,686.644	1,421.661	5,016.044	752.4066
Farmers	1,069.875	117.68625	1,086.291	271.5728	1,061.449	159.2174

Note: It is important to highlight that smart meters replaced conventional meters in MEPCO and LESCO for three-phase consumers only.

Based on these estimates, we calculated the payback period for consumers (see Chapter 7) if the AMI system is installed and the consumer covers the cost of the smart meters.

7. COST OF AUTOMATED METERING INFRASTRUCTURE (AMI)

7.1. Cost of AMI System

Power companies face numerous challenges when installing smart meters (SMs), including infrastructure costs, installation complexities, user acceptance, the need for a universal interface, network coverage, security concerns, privacy matters, and the availability of smart grid stations (Hussain, et al., 2016).

Although the initial costs of installing smart meters and upgrading the necessary infrastructure to support AMI and AMR systems can be high, the long-term benefits often outweigh these expenses. These benefits include bill savings for consumers, improved customer service, and reduced operational inefficiencies, ultimately leading to increased utility revenues, as discussed in Chapter 6.

7.1.1. IESCO AMI System Costs

IESCO is installing smart meters in Rawalpindi as part of the ADB-funded Second Power Distribution Enhancement Investment Program (RRP PAK 47190).

The turnkey contract for the AMI, valued at USD 120.8 million, includes the following components:

- Supply of metering equipment: USD 81.7 million
- Supply of communication equipment: USD 16.3 million
- Development of management systems, including the head-end system (HES), meter data management system (MDMS), billing system, and customer information system (CIS): USD 21.9 million
- Insurance: USD 0.7 million
- Installation: USD 0.2 million

The primary component of the AMI system is the cost of metering equipment, which accounts for approximately 68 per cent of the total expenses. This means that if consumers were to cover the cost of the meters themselves, the overall installation cost of the AMI for the utility would be reduced by 68 per cent. Additionally, the development of the data management system represents a one-time investment. As a result, the utility does not incur ongoing expenses for this aspect. The IESCO data management system (decentralised) has the capacity for 5 million consumers.

During discussions with IESCO officials, it was revealed that the cost per unit will decrease to approximately PKR 28 per consumer, compared to PKR 60 per consumer under the conventional billing system. This means that the billing costs will be reduced by PKR 32 per consumer with AMI implementation.[10]

It is essential to highlight that the installation of smart meters is financed through ADB loans. Thus, consumers do not incur direct costs for these meters. Nevertheless, the utility has to repay the ADB loan, including interest (Box 6), and these costs will be recouped through the consumer tariff. Besides, all IESCO consumers are currently subject to a monthly meter rent of PKR 1,000 included in their bills. The duration for which this charge will apply has not been disclosed.

Rather than imposing a uniform meter rent on all consumers, it would be significantly more equitable for only those utilising smart meters to bear the associated costs. Historically, in cases where meters were damaged or became defective, utilities would impose charges on the affected consumers for replacements. If consumers are responsible for covering the cost of the meter, it is reasonable to consider it their property. Furthermore, consumers should be allowed to select their vendors to purchase these meters. The utility's role would be to establish and communicate the standards and specifications necessary for compatibility with their system.

[10] The overall cost impact of the Advanced Metering Infrastructure (AMI) initiative is intricate to measure, as IESCO is focusing on a target of 1.2 million consumers.

7.1.2. LESCO AMI Estimates

Although LESCO was in the process of installing smart meters under the ADB loans, now it has worked out its investment plan for the AMI to be recouped through tariffs. According to its five-year investment plan (detailed in Annex 9), the total cost for 535,450 smart meters, including single-phase, three-phase, whole current, LT CT three-phase, whole current tube wells, and B1 types, is approximately PKR 16.2 billion. This amount also accounts for communication and operational costs (OPEX), estimated at a 7 per cent defection rate. However, it does not include the costs of decentralised data management systems, as the AMR data will be analysed (unlike IESCO) at the centralised level at the already established Power Information Technology Company (PITC) in Lahore[11].

- Out of PKR 16.2 billion, 90 per cent is the cost of smart meters.
- Even if the communication cost and OPEX are included (on average, all consumer types), this translates into PKR 30,335.4 per consumer.

Box 7. Centralised vs Decentralised Data Management System

The Pakistan Information Technology Company (PITC) possesses limited capabilities, often impeding the work of manufacturers by imposing restrictions on access to critical systems.

PITC's insufficient expertise and bureaucratic control significantly hinder effective infrastructure management. Implementing decentralised systems would enable DISCOs, such as LESCO, MEPCO, and FESCO, to manage their data centres autonomously. This decentralisation initiative aligned with international standards would mitigate reliance on the PITC. However, it would require substantial investment in infrastructure.

[11] Discussions with MEPCO officials indicated that the decentralised data management system at the DISCO level is unnecessary, as they will rely on the existing system at PITC.

7.1.3. Cost of AMI for all DISCOs

We assume that in the initial phase, all DISCOs continue to rely on a centralised data management system (PITC) to save costs. The total consumer base in nine DISCOs, excluding IESCO, is 30.991 million. Using the LESCO estimates, the projected total cost for all consumers will be PKR 940.2 billion.

It is pertinent to mention here that once the roll-out of smart meters across the country starts and competitive markets for smart meters develop, the cost will decrease due to economies of scale.

7.2. Cost of Smart Meters

There are significant variations in the prices of imported smart meters compared to those sold by local vendors. According to sources from IESCO, a single-phase meter costs USD 51, which equals approximately PKR 14,280 at an exchange rate of 280. In contrast, sources from LESCO report that a single-phase meter costs PKR 25,000, while three-phase meters range between PKR 42,000 and PKR 45,000.

During a meeting with MEPCO staff, we learned that six to seven vendors had been shortlisted to procure smart meters, although their names were not disclosed. We were also informed that MEPCO had already procured smart meters and was charging consumers PKR 46,000 or more, depending on the type of meter. This price included not only the cost of the meter but also installation charges, utility procurement, and storage charges.

We also identified six to seven registered vendors in Lahore during our survey. Furthermore, we found an online market offering imported smart meters manufactured in China. During our meetings with local vendors, we found them to be reluctant to disclose the prices of various types of smart meters. After further inquiry, one vendor revealed that a single-phase smart meter usually costs around PKR 55,000, while a three-phase meter was priced at about PKR 60,000. Similarly, commercial or industrial meters were also priced at about PKR

60,000. These prices excluded additional service or installation charges, according to the vendor.

Our findings indicate a lack of competitive market dynamics within the sector, as consumers are not presented with viable choices where smart meters are installed. Additionally, some experts raised concerns regarding the quality of locally produced meters, citing instances from the previous year in which 24,000 meters failed due to excessive rainfall, as they were not designed to be rain-resistant. Similar quality issues with imported smart meters have been observed, emphasising the need for improvements across both segments through market competition.

Furthermore, experts believed that, ideally, the meter should be considered the consumer's property following installation. However, in practice, it often remains the utility company's property, which complicates the cost structure. Consequently, the utility company incurs the meter's initial expense (e.g., in IESCO and LESCO) and recoups this cost through "meter rent" charges.

Local vendors asserted that a partnership between the government, local manufacturers, and DISCOs could effectively reduce investment costs over time. Presently, however, meters are owned by utilities, such as IESCO or LESCO, and consumers incur a rental fee for them, increasing their financial burden.

7.3. Payback Period for Consumers with Smart Meters

Using the savings estimates from Chapter 6 and accounting for the costs of smart meters, we calculated the payback period for consumers who pay for the smart meters upfront (Table 20 and Table 21).

For consumers with a single-phase connection, where the meter costs PKR 25,000, they will recover the cost within a year, assuming a discount factor of 10 per cent. The payback period for a meter priced at PKR 42,000 is less than two years. Even if a consumer is charged PKR 55,000 for the meter, as the vendor indicates, they will recover the cost within 27 months.

Since smart meters typically last 5 to 15 years, consumers can expect significant net benefits after the initial two-year period, with savings of 17 per cent or more.

Table 20. Payback Period for Consumers (Households) Covering the Cost of Smart Meters (Without Discount Factor)

Electricity Units Consumed kWh	Per Unit Electricity Rate (July-2024) (incl. GST, ED, FC Surcharge)	Average Electricity Bills PKR	17% Saving with Smart Meters PKR	Payback Period (months) Smart Meter Cost PKR 25,000	Payback Period (months) Smart Meter Cost PKR 42,000	Payback Period (months) Smart Meter Cost PKR 55,000
300	43.83	13,149	2,235	11	19	25
400	49.62	19,849.1	3,374	7	12	16
500	52.24	26,120.8	4,440	5	9	12
600	53.92	32,354.58	5,500	4	8	10
700	55.28	38,692.64	6,578	4	6	8

Table 21. Payback Period for Consumers (Households Covering the Cost of Smart Meters (With a Discount Factor 10%)

Electricity Units Consumed kWh	Per Unit Electricity Rate (July-2024) (incl. GST, ED, FC Surcharge)	Average Electricity Bills PKR	17% Saving with Smart Meters PKR	Payback Period (months) Smart Meter Cost PKR 25,000	Payback Period (months) Smart Meter Cost PKR 42,000	Payback Period (months) Smart Meter Cost PKR 55,000
300	43.83	13,149	2,235	12	21	27
400	49.62	19,849.1	3,374	8	14	18
500	52.24	26,120.8	4,440	6	10	14
600	53.92	32,354.58	5,500	5	8	11
700	55.28	38,692.64	6,578	4	7	9

8. CONCLUSION

8.1. Study Findings

Billing irregularities have long been a challenge for DISCOs in Pakistan, contributing to a financial deficit in the electricity sector for approximately 18 years. High technical and non-technical losses, along with ageing infrastructure, have undermined the system's reliability and resulted in significant increases in consumer bills.

From July 2023 to May 2024, the power sector experienced losses totalling PKR 509 billion, driven by outdated infrastructure, theft, and poor recovery rates.

The system's reliance on manual billing processes has made it susceptible to errors, as it depends heavily on meter readers and linemen. This reliance complicates the detection of electricity theft and can lead to issues such as meter tampering or fixed payments that do not reflect actual usage.

Smart meters, essential components of AMI and AMR technologies, improve data accuracy and overall system efficiency. They facilitate regular energy consumption monitoring, helping overcome the challenges posed by traditional billing methods.

The study documents the manual billing process in Pakistan and highlights its inconsistency, challenges, and costs.

A survey of 2,000 consumers, including households, businesses, and industries in Rawalpindi, Islamabad, Lahore, Multan, Faisalabad, and Sukkur, found that 79 per cent of them were willing to switch to an advanced metering system and pay for this transition. Among those seeking to replace conventional meters with smart meters, 30.5 per cent of domestic consumers were willing to cover 100 per cent of the smart meter's costs. Furthermore, consumers with an income exceeding PKR 200,000 were willing to bear 100 per cent of the smart meter's costs.

A few years ago, the power sector installed smart meters in three DISCOs (LESCO, MEPCO, and PESCO) through a USAID-funded pilot project. A centralised meter data management system was also established at WAPDA-PITC.

In our survey of 800 consumers – 400 from LESCO and 400 from MEPCO – we found that smart meters were ineffective where consumer consent and opinions were overlooked. Effective outcomes require prior knowledge of smart meters.

In areas where these conditions are met, consumers were largely satisfied as their billing irregularities decreased, electricity supplies became more reliable, and they managed to reduce their electricity consumption.

The study estimated that consumers equipped with smart meters, combined with heightened awareness and empowerment, can realise (on average) up to 17 per cent savings in electricity units.

From the utilities' perspective, LESCO projected savings with smart (AMR) meters from FY2016-17 to FY2023-24 on three loss-making 11KV feeders (Ali Hajvari, Madina Town, and Sabzi Mandi) were found to be PKR 960 million. MEPCO achieved an incremental revenue of PKR 2.2 billion over 11 months with 150,000 smart meters.

The study estimated that consumers who buy smart meters upfront, costing PKR 25,000 for a single-phase connection, can recover this expense within a year, assuming a 10 per cent discount. The study reveals significant price disparities between imported and locally sold smart meters, underscoring a notable lack of competition in the market.

8.2. Way Forward

The adoption of AMI, coupled with the implementation of smart meters, represents a critical opportunity for utility companies to enhance revenue generation. This technology serves as an effective mechanism to mitigate billing irregularities while simultaneously improving the grid's reliability. In Pakistan's power sector, more than fifty per cent of the existing challenges can be effectively addressed through this technological transformation.

This initiative must be implemented across all DISCOs. During the initial phase, it is advisable to maintain a centralised data management system to optimise cost efficiency. Nonetheless, once utilities realise extra revenues, they must develop decentralised data management systems within two to three years.

Achieving a 100 per cent rollover of smart meters is not feasible due to the complexities involved, DISCOs' inability, and the varying living standards of the population. However, this goal can be approached through a phased implementation plan as follows:

Year 1: All three-phase consumers, industrial consumers, and agriculture tube well connections.

Year 2 and Year 3: Single-phase domestic consumers and retailers may be targeted in all urban centres. For lifeline and protected consumers, the cost of smart meters can be subsidised through a social protection program or a special subsidy package.

Year 4 and Year 5: All consumers across the country, where communication infrastructure is available, must be connected to the AMI system.

Consumers are willing to invest in smart electricity meters, provided they are aware of their potential benefits. They should have the option of selecting between one-time payment or monthly instalment plans on their electricity bills.

An open market for smart electricity meters should be established, mirroring the framework of the smartphone market. Consumers must be free to choose the smart meter that best meets their preferences and meet system specification standards. In instances where consumers bear the cost of the meter, they should not incur any rental fees on their bills. Ultimately, ownership of the meters should reside with the consumers. Other overhead costs can be covered through annual Public Sector Development Programmes (PSDPs) instead of relying on loans from donors.

As the nationwide deployment of smart meters commences and market competition intensifies, economies of scale are expected to drive down their prices.

Empowering consumers is critical for unlocking smart meters' full potential. This objective can be achieved by integrating a mobile application that operates in conjunction with smart meters.

It is imperative to prioritise equity and fairness when considering DISCOs' investment plans during tariff determinations. Consumers should be charged exclusively for the services rendered to them.

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ANNEXES

Annex A1. Questionnaire - Willingness to Replace Conventional Meters and Pay for New Smart Meters

Questionnaire Number	0	0	0	0

Assalam-o-Alaikum

My name is ___________. I am reaching out as part of a study conducted by PIDE, focusing on the assessment of the utility, knowledge, and willingness to adopt smart meters. If you are not familiar with smart meters, I will provide you with a brief introduction. Our aim is to understand the benefits of installing smart meters and the challenges associated with their implementation. Your insights will play a crucial role in shaping the outcomes of this study. The interview is expected to take approximately 30 minutes, and I want to assure you that all information gathered will be treated with utmost confidentiality. May I proceed with the interview now?

Section 1. Identification	
1. Household type	1. Household 2. Commercial
2. City	1. Islamabad 2. Rawalpindi 3. Lahore 4. Faisalabad 5. Multan 6. Sukkar
3) Name/ location	
4) Phone number	
Strictly Confidential *This information is confidential, and the name and address of the respondent will not be used for any other purpose than research. Names will not be linked to the information gathered except as required for the purpose of follow-up in the study, handled only by project staff.*	

Section 2. Consumer Profile		
2a. Domestic Consumer Profile		
Q1	Gender	1. Male 2. Female
Q2	Employment Status	1. Employer/Self-Employed (own business) 2. Government Paid Employee 3. Private Paid Employee 4. Daily Wage/Casual Worker 5. Unemployment 6. Others (specify)
Q3	Monthly income (PKR) - Head of the Household?	1. Below 50,000 PKR 2. Between 50,000 & 100,000 PKR 3. Between 100,000 & 200,000 PKR 4. Between 200,000 & 400,000 PKR 5. Between 400,000 & 600,000 PKR 6. Above 600,000 PKR 7. Don't Answer
Q4	Education – Head of the Household?	1. No education 2. Primary 3. Middle 4. Matric 5. Intermediate 6. BA 7. BS/MA/MSc 8. MPhil 9. PhD 10. Other (specify)
Q5	Family size (total family members)?	
2b. Personal Profile (Commercial) Consumer		
Q1	Business Type?	1. Retailer 2. Wholesaler 3. SMEs

Q2	SME Sector?		
Q3	Income?	1. Below 50,000 PKR 2. Between 50,000 & 100,000 PKR 3. Between 100,000 & 200,000 PKR 4. Between 200,000 & 400,000 PKR 5. Between 400,000 & 600,000 PKR 6. Above 600,000 PKR 7. Don't Answer	
Q4	Education of the owner?	1. No education 2. Primary 3. Middle 4. Matric 5. Intermediate 6. BA 7. BS/MA/MSc 8. MPhil 9. PhD 10. Other (specify)	

Section 4. Willing to Pay for Smart Meters			
Q1	Are you aware of Smart Meters?	1. Yes 2. No	
Q2	If yes, how do you know about Smart Meters?	1. Social Media 2. Electronic/Print Media 3. Friends & Relatives 4. Others 5. Don't know	
Q3	Do you want to replace the existing manual meter with a smart meter?	1. Yes 2. No 3. Not Sure	
Q4	What is the reason? Why you don't want to replace the existing manual meter with a smart meter?		

Q5	If yes, how much do you want to pay for it?	1. Full Payment (100%) 2. 75 per cent 3. 50 per cent 4. less than 50 per cent 5. Don't know	
Q6	What is the mode of payment? Do you want to pay in instalments or not?	1. Instalments 2. One-time payment 3. Don't know or not sure 4. Not applicable	
Q7	In your opinion, should (the installation of smart meters) be optional or mandatory?	1. Mandatory 2. Optional 3. Don't know or not sure 4. Not Applicable	
Q8	What type of smart meter would you like to get installed?	1. Post-paid smart meter 2. Prepaid smart meter 3. Don't know or not sure 4. Not Applicable	
Section 5. Electricity Billing			
Q1	What was your average monthly Electricity bill last month?		
Q2	What is your average monthly Electricity bill in Summer?		
Q3	What is your average monthly Electricity unit consumption in winter?		
Q4	What was your average monthly Electricity unit consumption last month?		
Q5	What is your average monthly Electricity unit consumption in summer?		
Q6	What is your average monthly Electricity unit consumption in Winter?		

Q7	Do you notice in which slab your unit consumption falls?	1. Yes, always 2. Often 3. Rarely 4. Never 5. Don't know	
Q8	Have you ever noticed/monitored your meter reading?	1. Never noticed 2. Rarely 3. Often 4. Don't know	
Q9	Have you ever felt irregularity in electricity bills?	1. Yes 2. No 3. Don't know	
Q10	If yes, what type of irregularities in billing?	1. Overbilling/reading 2. Defects in meters 3. Other 4. Don't know	
Q11	If yes, how overbilling is impacting your other consumption pattern?	1. Reduction in other Expenditures 2. No effects on other expenditures 3. Don't Know	
Q12	Have you ever complained to the concerned authority?	1. Never Complained 2. One time 3. Two to Three times 4. More than three times 5. Don't know	
Q13	What was the response of the concerned authorities?	1. Responded, and the problem was fixed 2. Responded, but the problem was not fixed 3. Not Responded 4. Don't know 5. Not Applicable	

Q14	Do you have any other source of electricity? How often do you use/	1. Yes (e.g., Generator, Solar) 2. No 3. Don't know 4. Refuse to answer 5. Don't know 6. Always	
Q15	Do you use energy-efficient electronic appliances?	1. Yes 2. No 3. Don't know 4. Refuse to answer 5. Don't know 6. Refuse to answer	
Q16	Are you upset due to rising electricity prices/bills?	1. Yes 2. No 3. Don't know 4. Refuse to answer	
Q17	If yes, how do you manage it?	1. Reducing food expenditures 2. Compromising quality of life by reducing non-food expenditure 3. Loan 4. Help from friends/relatives 5. Others 6. Refuse to Answer	

Annex A2. Areas Covered in the Survey (Consumer Willingness to Switch to Smart Meters)

Islamabad

Sample Size (250 consumers)

Areas Covered: G-6 (25 forms), G-8 (25 forms), G-10 (25 forms), G-13 (25 forms), F-7 (25 forms), I-9 (25 forms), I-10 (25 forms), Barakahu (25 forms), Shahzad Town (25 forms), Bari Imam (25 forms)

Rawalpindi

Sample (250 consumers)

Areas Covered: Harley Street and Surrounding 100 forms/units), Saddar (50 units), Westridge I and II (50 units), Adiala/ Lalazar Coloney (50 units);

Lahore

Sample Size (500 Consumers)

Areas Covered: Alama Iqbal Town (50), Rana town (50), Rajpoot Town (50)

DHA (50), Gulberg & Cavalry (25), Model Town (25), Anarkali (25), Liberty (25)

Ichra (50), Dehli Gate (50), Misri Shah (50), Shah Alam Market (50), Mazung (50), Cantt Saddar (25)

Faisalabad

Total Sample Size (400 units) – 200 Households (HH) and 200 (SMEs & Commercial)

Areas Covered for Domestic Consumers: D-Ground (25), Gulberg (25), Jinnah Colony (30), Shadab Mor/ Saifabad (30), Mansoorabad (30), Housing Colonies around Canal Road (30), Madani Chowk (30)

SMEs (50), Retailers and Wholesaler (150) - covering the entire city of Faisalabad

Multan

Total Sample Size (400 units) – 240 HH and 160 (SMEs and Commercial)

Areas Covered: WAPDA Town (10), Model Town (10), Sahr Villas (10), Royal Orchard (10), Garden Town (10), Askari Fort (10), MDA (10), Teachers Colony (10), Punjab Small Industries Housing Society (20), Fort Avenue (10), Peeran Ghaib (10), Shah Rukan Alam (10), Fatima Town (10), Qasim Pur Colony (10), Farid Canal colony (10), Hashmi Canal View Colony (10), Suraj Miyani (10), Al Mujahid Colony (10), Nawab Pur Road Area (10), Masoom Shah Road (10), Hussain Aghai (10)

Annex A3. Questionnaire – Smart Meter Effectiveness

Questionnaire Number	0	0	0	0

Assalam-o-Alaikum

My name is _____________. I am reaching out as part of a study conducted by PIDE, focusing on the assessment of the utility, knowledge, and willingness to adopt smart meters. The interview is expected to take approximately 15 minutes, and I want to assure you that all the information gathered will be treated with utmost confidentiality. May I proceed with the interview now?

Section 1. Identification								
1. District/City	1-Lahore, 3-Multan							
4. Gender of the respondent	1- Male, 2-Female							
4. Phone/Mobile No (optional)								
5. Is a Smart Meter installed	1-Yes 2- No→Q-7							
6. Type of smart meter	1- Single Phase 2- Two Phase 3-Three Phase 4- Any Other (Please Specify)							
6. Installed Smart Meter No. (optional)								
7. Type of Connection	1-Household →Sec. 2a 2-Industry →Sec. 2b 3-Commercial→Sec, 2c							
7-Date of enumeration								
8. Name of enumerator								
Strictly Confidential *This information is confidential, and the name and address of the respondent will not be used for any other purpose than research. Names will not be linked to the information gathered except as required for the purpose of follow-up in the study, handled only by project staff.*								

Section 2. Consumer Profile		
2a. Household		
Q1	Occupation of the Household Head	1- Self-employed 2- Paid-Employee 3- Other (Specify)
Q2	Income of the household (Monthly)	1- Below 50,000 2- Between50,000 &100,000 3- Between 100,000 &300,000) 4- Between 300,000-400,000 5- Above 500,000
Q3	Education of the Household Head	1. Uneducated 2. Below Matric 3. Matric & Above (FA/FSc) 4. Graduate 5. Above Graduate
2b. Industry (This section is only for the industrial sector)		
Q1	Industry Type	1- SMEs 2- Large Scale 3- Other (Please Specify)
Q2	Sector	
2c. Commercial		
Q1	Type of business	1- Retailer 2- Wholesale
Q3	Education of owner	1. Uneducated 2. Below Matric 3. Matric & Above(FA/FSc) 4. Graduate 5. Above Graduate

Section 3: Effectiveness of Smart Meters			
Q1	When was your smart meter installed?	1- Months (convert years into months) 2- Don't know	
Q2	Did someone take your consent before the installation?	1. Yes 2. No 3- Don't Know	
Q3	Did you face any issues prior to the installation of the smart meter?	1- Yes 2- No 3- Don't Know	
Q4	Please mention what type of issue you are facing (Skip this question if the answer in Q3 is "Not" or Don't Know")	1. Overbilling/Over reading 2. Meter Related Issue 3. Any other(write the issue)	
Q5	Have you ever faced any issues after the installation of Smart Meter?	1- Yes 2- No 3- Don't Know	
Q6	Please mention what type of issue you are facing (Skip this question if the answer in Q5 is "Not" or Don't Know")	1- Overbilling/Over reading 2- Meter Related Issue 3- Any other(write the issue)	
Q7	Are you satisfied with the performance of the smart meter	1. Satisfied 2. Unsatisfied/Dissatisfied 3. Don't Know	
Q8	What is the level of satisfaction (rate 1 to 5)? (Skip this question if the answer in Q7 is "Unsatisfied" or Don't Know")	Type values 1 to 5 (lowest to highest level of satisfaction)	
Q9	If unsatisfied/dissatisfied, what are the reasons? (Skip this question if the answer in Q7 is Satisfied).	1. Not-user friendly 2. Technical issues/glitches 3. Billing problems 4. Any Other (mention)	
Q10	Do you face any problems with paying bills for the smart meter?	1. Yes 2. No 3. Don't Know	

Q11	Please identify the top three issues/problems (Skip this question, if the answer in Q10 is "No or Don't Know"	1. ------------------------------------ 2. ------------------------------------ 3. ------------------------------------	
Q12	How often do you check your meter reading **Before** the installation of smart meters?	1. Yes, daily 2. Yes, weekly 3. Yes, fortnightly 4. Yes, once a month 5. Never 6. Don't Know	
Q13	How often do you check your meter reading **After** installation of smart meters?	1- Yes, daily 2- Yes, weekly 3- Yes, fortnightly 4- Yes, once a month 5- Never 6- Don't Know	
Q14	What are the reasons for not noticing/monitoring the meter reading after the installation of the smart meter? Please identify major reasons (**keep this question if the answer in Q13 is "Never" or "Don't Know" otherwise skip it**)	1. ------------------------------------ 2. ----------------------------------- 3. ------------------------------------	
Q15	Do you know the slabs of unit consumption?	1- Yes, before the installation of smart meters 2- Yes, after the installation of smart meters 3- No 4- Don't Know	
Q16	How do you know this? Please identify the source of information (**Skip if the answer in Q15 is NO or Don't Know**)	1. Media/Social Media 2. DISCOs/Meter Reader etc. 3. Friends/Relatives 4. Others (please specify)	
Q17	Do you think the installation of smart meters is helping you to reduce your electricity bills as compared to smart meters for the same months?	1- Yes 2- No 3- Don't Know	

Q18	Please mention how much on average it reduces your bill (Skip if the answer in Q 17 is "No" or "Don't Know")	1- Less than 5 per cent 2- 5 to 10 per cent 3- 10 to 20 percent 4- 20 to 30 percent 5- 30 to 40 percent 6- 40 to 50 percent 7- 50 to 60 per cent 8- Above 60 per cent	
Q19	What is your overall satisfaction with the smart meter in terms of reducing your bill/reading?	1. Extremely disappointed 2. Disappointed 3. Neutral 4. Satisfied 5. Highly satisfied	
Q20	Reasons for being satisfied with smart meters. (Multiple Choice Options). (Skip if Q19 is "1 to 3")	1- Reduction in Overbilling/over-reading 2- Avoiding higher slabs by monitoring the meter reading daily 3- Any Other (Please specify)	
Q21	Do you know who bears the cost of these meters?	1. Yes 2. No	
Q22	Please mention who bears the cost. (Skip if Q21 is "No")	1- Government of Pakistan 2- By Donors 3- Others	
Q23	In future, if the need arises, will you be willing to pay to replace these meters?	1. Yes 2. No 3. Don't Know	
Q24	If yes, what would be your preference to pay?	1- Onetime payment 2- Instalments 3- Others (Please specific)	
Q25	Are you aware of your daily real-time usage of electricity consumption data?	1. Yes 2. No	
Q26	What is your average monthly unit consumption of electricity **Before** the installation of SM (in terms of units?	1. Summer: ---------------------- 2. Winter: ---------------------------- 3. Not willing to share	

Q27	What is your average monthly unit consumption of electricity **After** the installation of SM (in terms of units?	1- Summer: ---------------------- 2- Winter: ---------------------------- 3- Not willing to share	
Q28	What is your average monthly unit consumption of electricity bill **Before** the installation of SM (in PKR)?	1- Summer: ---------------------- 2- Winter: ---------------------------- 3- Not willing to share	
Q29	What is your average monthly electricity bill **After** the installation of SM (in PKR)?	1- Summer: ---------------------- 2- Winter: ---------------------------- 3- Not willing to Share	

Annex A4: Areas Covered for Survey (Smart Meter Effectiveness)

Lahore

Awan Tower, Amna Park, Mughal Pura, Madina Tower, Taj Bagh, Kachi Abadi, Baghban Pura, and Crown Park

Multan

Gulghust Colony, Bosan Road, Chungi No. 6, Shah Rukan Alam, Chowk Kumharan, Masoom Shah Road, Officers Colony, Nawab Pur, Askari Colony, Balochan Wala, Mouza Dhull Najeeb, Chak Yar Wala, Chowk Wains, Basti Bagh Wali, Kabir Wala, Sandrana, Bawa Safra, Rasheed Abad, Ibrahim Pur, Tulumba, Mouza Ibrahim Pura, Peeple Wala, Khanewal Road, Lutfabad, Katchery Road, Shamsabad, Qasim Bagh, Buch Villas, Shujabad,

Annex A5. Manual Billing Cost per Consumer

Table A5.1. Manual Billing Cost Per Consumer - LESCO

Heads	Expenditure (PKR)	Unit	Total Per Month (PKR)
Meter Reader's Salary/ Month	60,000	Meter Readers: 2606	156,360,000
Supervisor	100,000	Subdivisions: 195	19,500,000
Bike Maintenance/Month	2,000	Half of the meter readers need bike maintenance	2,606,000
Mobile Expense	50,000	Replace once a year	10,858,333
Bill Printing/Month	20	Total consumers: 5,451,212	109,024,240
Bill Distribution	5	Local courier service	27,256,060
Petrol Cost/Day	600	Meter readers work 22 days a month	34,399,200
Overtime Salary		4 hours a day	78,180,000
Total Cost			438,183,833
Billing Cost per Consumer			**80.1**

Note: This is a very conservative estimate as it does not include the costs of head office departments involved in the process. Overtime salary is estimated after calculating salary per hour for 22 days.

Table A5.2. Manual Billing Cost Per Consumer - SEPCO

Departs.	Infrastr-ucture	No of Employees	Avg Salary Month (PKR)	Avg. Infra. Cost Per Employee per Month (PKR)	Off. Cost (PKR)	Total Monthly Salaries (PKR)	Infra. Cost Per Employee (PKR)
Meter Readers	Smart Phones /Selfie Sticks/ Vehicles	400	65,000	20,000		26,000,000	8,000,000
Subdivision Office	16 offices / 16 Compu-ters	30	90,000	20,000	25,000	2,700,000	600,000
MIS office	1 office	35	120,000	20,000	30,000	4,200,000	700,000
PIT	1 office	15	200,000	50,000	40,000	3,000,000	750,000
Bills Dist.		110	50,000	20,000	0	5,500,000	2,200,000
Revenue Office		36	70,000	20,000	0	2,520,000	720,000
Finance Depart.		7	`100,000	20,000	50,000	700,000	140,000
Total					145,000	44,620,000	13,110,000
Cumulative Total							57,875,000
No. Consumers							823,586
Billing Cost per Consumer							**70.3**

Annex A6. Results – Willingness Survey

Table A6.1. Consumers Per CentDistribution

Consumers	City						
	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Sukkur	Total
Domestic	66.41	73.18	77.96	59.50	49.51	52.0	63.09
Commercial*	33.59	26.82	22.04	40.50	50.49	48.0	36.91

*Includes SMEs

Table A6.2. Commercial Consumer's by Type (%)

Business Type	City						
	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Sukkur	Total
Retail	86.21	88.57	70.91	87.65	59.62	70.30	77.21
Wholesale	13.79	11.43	23.64	11.11	19.71	23.45	17.19
SMEs	0.00	0.00	5.45	1.23	20.67	6.25	5.60

Table A6.3. Domestic Consumers by Income Group (%)

Income Group	City						
PKR	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Sukkur	Total
Below 50,000	15.12	22.51	39.33	11.76	33.33	44.23	27.71
50,000 to 100,000	26.74	50.79	14.91	28.15	25.00	45.08	31.78
100,000 to 200,000	33.72	18.32	5.40	37.82	14.71	3.85	18.97
200,000 to 400,000	13.95	8.38	0.51	15.55	18.63	6.84	10.64
400,000 to 600,000	3.49	0.00	0.00	0.84	7.35	0.00	1.95
Above 600,000	6.40	0.00	0.00	0.42	0.00	0.00	1.14
Refused to Answer	0.58	0.00	39.85	5.46	0.98	0.00	7.81

Table A6.4. Commercial Consumers by Income and City (%)

Income Group	City						
PKR	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Sukkur	Total
Below 100,000	9.20	15.71	24.55	46.30	35.58	18.75	25.02
100,000 to 200,000	29.89	51.43	15.45	41.36	0.96	21.25	26.72
200,000 to 400,000	21.84	21.43	1.82	12.35	2.40	24.6	14.07
400,000 to 600,000	5.75	7.14	0.00	0.00	2.40	25.0	6.72
Above 600,000	32.18	4.29	0.00	0.00	2.40	10.4	8.21
Refused To Answer	1.15	0.00	58.18	0.00	56.25	0.00	19.26

Table A6.5. Smart Meter Awareness (%)

	City						
	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Sukkur	Total
Aware	2.70	37.16	16.23	52.00	20.15	34	27.04
Not Aware	97.30	62.84	83.77	48.00	79.85	66	72.96

Table A6.6. Source of Information about Smart Meters (%)

	City					
	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Total
Social media	0.00	32.99	66.67	3.37	36.14	25.84
Electronic/Print media	28.57	0.00	6.17	1.92	0.00	2.31
Friends/ Relatives	42.86	44.33	25.93	25.96	46.99	33.61
Others	28.57	22.68	1.23	68.75	16.87	38.24

Table A6.7. Willingness to Replace Conventional Meters with Smart Meters

	City						
	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Sukkur	Total
Yes	93.82	68.97	78.16	82.5	73.54	78.8	79.30
No	1.93	27.97	14.43	2.25	12.14	21.2	13.32
Not Sure	4.25	3.07	7.41	15.25	14.32	0	7.38

Table A6.8. Willingness to Replace Among Those Who Were Not Aware But Informed By the Enumerators (%)

	City						
	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Sukkur	Total
Yes	93.65	62.80	78.47	70.83	70.52	67.19	73.91
No	1.98	32.93	14.35	0.52	13.68	32.81	13.32
Not sure	4.37	4.27	7.18	28.65	15.81	--	7.38

Table A6.9. Reasons for Not Replacing Conventional Meters (%)

	City					
	Islamabad	Rawalpindi	Lahore	Multan	Faisalabad	Total
No Budget, if free will replace	6.25	24.69	1.83	32.86	0	11.94
First, see then decide	62.5	0	24.77	38.57	47.71	30.13
No Trust in Govt.	0	0	45.87	1.43	0	13.25
Not Interested	25	20.99	19.27	0	37.61	21.56

Solar Installed or Planning to Install	6.25	51.85	8.25	27.14	14.68	22.6
WAPDA Employee (free electricity)	0	2.47	0	0	0	0.52

Table A6.10. Willingness to Replace by Consumer Category (%)

	Domestic	Commercial	Total
Yes	84.00	69.54	78.97
No	9.88	14.29	11.41
Not Sure	6.11	16.17	9.61

Table A6.11. Willingness to Replace (Domestic Consumers) by Income (%)

PKR	Below 500,000	50,000 to 100,000	100,000 to 200,000	200,000 to 400,000	400,000 to 600,000	Above 600,000	Refused to Answer	Total
Yes	79.25	85.89	89.32	88.89	100.00	100.00	75.44	84.00
No	13.21	7.84	5.98	11.11	0.00	0.00	14.04	9.88
Not Sure	7.55	6.27	4.70	0.00	0.00	0.00	10.53	6.11

Table A6.12. Consumer Willingness to Replace (Commercial) by Income (%)

PKR	Below 100,000	100,000 to 200,000	200,000 to 400,000	400,000 to 600,000	Above 600,000	Refused to Answer	Total
Yes	66.67	81.08	83.61	73.33	83.33	55.49	69.54
No	11.28	11.49	6.56	26.67	8.33	22.53	14.29
Not Sure	22.05	7.43	9.84	0.00	8.33	21.98	16.17

Table A6.13. Consumer Willingness to Pay (%)

	City						
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Sukkur	Total
Domestic	66.41	73.18	77.96	49.51	59.50	50.0	
Commercial	33.59	26.82	22.04	50.49	40.50	50.0	

Table A6.14. Willingness to Pay by Business Type (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Retail	86.21	88.57	70.91	59.62	87.65	75.51
Wholesale	13.79	11.43	23.64	19.71	11.11	16.48
SMEs	0.00	0.00	5.45	20.67	1.23	8.01

Table A6.15. Consumer Behaviour – Notice Consumption Slabs (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Always	22.01	67.43	56.51	48.79	37.25	47.24
Often	18.15	13.79	29.86	2.18	12.00	15.78
Rarely	12.74	4.21	4.01	9.71	6.75	7.15
Never	47.10	14.18	4.61	37.14	17.75	22.17
Don't Know	0.00	0.38	5.01	2.18	26.25	7.65

Table A6.16. Consumer Behavior - Monitor Meter Reading (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Always	16.22	33.72	1.60	16.02	23.75	16.33
Often	20.85	27.59	31.26	2.43	20.75	20.48
Rarely	12.74	22.22	9.82	17.96	26.25	17.42
Never	50.19	16.09	53.31	63.59	25.00	43.69
Don't Know	0.00	0.38	4.01	0.00	4.25	2.08

Table A6.17. Billing Irregularity (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Yes	64.86	73.95	77.15	90.53	67.25	75.81
No	34.75	26.05	16.83	5.34	14.75	17.64
Don't Know	0.39	0.00	6.01	4.13	18.00	6.55

Table A6.18. Type of Irregularity (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Over Billing/Incorrect Reading	78.57	90.16	89.09	95.17	83.64	88.54
Defect in Meter	20.83	9.33	1.56	4.02	11.15	7.49
Other	0.60	0.52	3.90	0.54	4.09	2.16
Don't Know	0.00	0.00	5.45	0.27	1.12	1.80

Table A6.19. Impact of Over-Billing on Other Expenditures (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Reduction in other Expenditures	92.26	82.38	88.05	52.01	78.44	76.22
No Effect	6.55	17.62	8.05	44.50	20.45	21.40
Never Noticed	1.19	0.00	3.90	3.49	1.12	2.38

Table A6.20. Billing Irregularity Complaints (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Never	27.98	28.50	75.32	56.03	21.19	47.41
Once	7.74	36.27	13.25	19.84	61.71	26.95
Twice or thrice	22.02	20.73	3.12	19.03	13.01	14.05
More than three	42.26	14.51	8.31	5.09	4.09	11.60

Table A6.21. Response from Authorities Against Complaints

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Yes, Problem Fixed	21.49	39.86	11.58	29.88	14.15	23.42
Yes, Problem Not Fixed	66.12	42.03	21.05	15.85	79.25	48.22
No Response	11.57	18.12	54.74	54.27	6.60	26.58
Don't Know	0.83	0.00	12.63	0.00	0.00	1.78

Table A6.22. Other Sources of Electricity (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Solar	5.41	14.18	5.21	27.91	19.50	14.75
Generator	15.83	10.73	8.42	8.50	0.75	8.14
No Other Source	78.76	75.10	86.37	63.59	79.75	77.12

Table A6.23. Use of Energy Efficient Appliances (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Yes	86.49	99.23	52.71	97.33	87.75	81.81
No	13.51	0.77	46.69	2.18	9.50	17.31
Don't know	0.00	0.00	0.60	0.49	2.75	0.87

Table A6.24. % Amount Willing to Pay for Smart Meters

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Full Payment (100%)	29.63	22.78	12.05	49.50	17.88	25.52
75 %	22.22	3.33	5.38	2.97	6.36	7.68
50 %	41.15	25.00	14.10	15.84	19.70	21.65
< 50%	5.76	46.67	64.10	31.02	28.18	37.00
Don't know	1.23	2.22	4.36	0.66	27.88	8.16

Table A6.25. Payment Mode (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Instalment in Monthly Bills	64.20	71.98	46.67	47.52	41.52	51.80
One Time Payment	35.80	25.27	46.67	50.83	28.48	38.88
Don't Know	0.00	1.10	0.00	0.00	0.00	0.14
No Response	0.00	1.65	6.67	1.65	30.00	9.19

Table A6.26. Smart Meter Mandatory (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Mandatory	77.78	23.63	79.49	2.97	66.36	53.18
Optional	22.22	71.43	13.08	97.03	28.48	43.02
Don't Know	0.00	4.95	7.44	0.00	5.15	3.80

Table A6.27. Smart Meter: Post-Paid or Prepaid (%)

	City					
	Islamabad	Rawalpindi	Lahore	Faisalabad	Multan	Total
Post-Paid	84.77	79.67	75.90	75.58	81.52	79.07
Prepaid	15.23	17.58	10.00	24.09	11.52	15.12
Not Sure	0.00	2.75	14.10	0.33	6.97	5.80

Annex A7. General Survey Information – Smart Meter's Impact

Table A7.1. Consumer Type Surveyed (%)

	Lahore	Multan	Total
Domestic	76.75	7.44	41.97
Industry	5.50	11.66	8.59
Commercial	17.75	41.44	29.64
Agriculture	0.00	39.45	19.80

Table A7.2. Industry Type Surveyed (%)

	Lahore	Multan	Total
SMEs	100	89.36	92.75
Large	0	10.64	7.25

Table A7.3. Commercial Type Surveyed (%)

	Lahore	Multan	Total
Retail	100	70.06	78.99
Wholesale	0	29.94	21.01

Table A7.4. Level of Consumer Satisfaction with Smart Meter (%)

Satisfaction Level 1=Very Low to 5 = Very High	Lahore	Multan	Total
3	51.38	6.07	16.92
4	39.45	61.85	56.48
5	9.17	32.08	26.59

Table A7.5. Level of Consumer Satisfaction with Smart Meter (%)

Satisfaction Level	Lahore	Multan	Total
Extremely Disappointed	39.50	0.25	19.80
Disappointed	13.50	0.99	7.22
Neutral	43.75	26.30	34.99
Satisfaction	3.00	63.77	33.50
Highly Satisfied	0.25	8.68	4.48

Table A7.6. Reduction in Electricity Bills (%)

Reduction in Consumer Bills	Lahore	Multan	Total
No	100.00	30.48	33.44
Yes	0.00	69.52	66.56

Table A7.7. Problems Faced Before Smart Meter (%)

	Lahore	Multan	Total
Yes	0.75	38.21	19.55
No	99.25	52.11	75.59
Don't Know	0.00	9.68	4.86

Table A7.8. Problems faced After Smart Meter (%)

	Lahore	Multan	Total
Yes	52.50	17.87	35.12
No	47.00	80.89	64.01
Don't Know	0.50	1.24	0.87

Table A7.9. Problem Types – After Smart Meter (%)

	Lahore	Multan	Total
Overbilling/Overreading	74.76	88.89	78.37
Meter Related Issue	24.76	5.56	19.86
Others	0.48	5.56	1.77

Table A7.10. Meter Reading Habit Before Smart Meters (%)

	Lahore	Multan	Total
Daily	1.75	1.49	1.62
Weekly	2.50	19.85	11.21
Fortnightly	3.75	4.71	4.23
Once a Month	45.75	59.55	52.68
Never	43.25	9.93	26.53
No Answer	3.00	4.47	3.74

Table A7.11. Meter Reading Habits After Smart Meters (%)

	Lahore	Multan	Total
Daily	1.25	12.16	6.72
Weekly	1.50	15.38	8.47
Fortnightly	0.50	8.44	4.48
Once a Month	29.50	54.59	42.09
Never	63.50	9.18	36.24
No Answer	3.75	0.25	1.99

Table A7.12. Reasons for Still Not Reading Meters Regularly (%)

	Lahore	Multan	Total
Lack of Information	100.00	0.00	87.62
Online Bill Reading	0.00	100.00	12.38

Table A7.13. Knowledge of Tariff Slabs (%)

	Lahore	Multan	Total
Yes	23.75	59.31	41.59
No	76.25	40.69	58.41

Table A7.14. Knowledge of Daily Energy Consumption (%)

	Lahore	Multan	Total
Yes	2.25	63.03	32.75
No	92.75	30.77	61.64
Don’t Know	5.00	6.20	5.60

Table A7.15. Reduction in Electricity Consumption (Demand Management)%

	Lahore	Multan	Total
Yes	5.75	65.76	35.87
No	92.00	16.87	54.30
Don’t Know	2.25	17.37	9.84

Table A7.16. Knowledge about Who Pays for Smart Meters, when Installed (%)

	Lahore	Multan	Total
Yes	50.50	86.85	68.74
No	45.00	9.18	27.02
Don’t Know	4.50	3.97	4.23

Table A7.17. If Yes, Who? (%)

	Lahore	Multan	Total
Government	99.00	26.29	52.90
By donors	1.00	1.43	1.09
Others	0.50	72.29	46.01

Table A7.18. Preference for Meter Types

	Lahore	Multan	Total
Prepaid SM	0.00	40.65	14.97
Postpaid SM	75.83	58.54	69.46
Don’t Know	24.17	0.81	15.57

Table A7.19. Payment Mode When There is a Need to Replace Existing Smart Meters

	Lahore	Multan	Total
One-time payment	63.98	17.07	46.71
Instalments	36.02	56.91	43.71
Others	0.00	26.02	9.58

Annex A8. Regression Results

Table A8.1. Robust Regression Estimation: Log of Average Monthly Electricity Unit Consumption

Variables	Coefficient	Robust Std. err.	t-stat	P>t
Meter Reading (1=Yes, 0=No)	-0.11158	0.053929	-2.06	0.046
Knowledge of Slabs ((1=Yes, 0=No)	-0.25639	0.148099	-1.73	0.092
Over-Billing Reduction (1=Yes, 0=No)	-0.15647	0.069796	-2.24	0.035
Consumer Category				
Industry [Yes=1, 0=No (Household)]	1.702028	0.331054	5.14	0.000
Commercial [Yes=1, 0=No (Household)]	1.662221	0.286189	5.81	0.000
Farmers [Yes=1, 0=No (Household)]	0.24546	0.277195	0.89	0.376
_constant	6.582391	0.390127	16.87	0.000

Annex A9. Cost of Smart Meters- LESCO

Sr No	Area Type	Meter Type	Est. Unit Rate PKR	FY23		FY24		FY25		FY26		FY27	
				Qty	Est. Cost (PKR million)	Qty	Est. Cost (PKR million)	Qty	Est. Cost (PKR million)	Qty	Est. Cost (PKR million)	Qty	Est. Cost (PKR million)
CAPEX													
1	High Loss Feeders	Single Phase GPRS/GSM	22,000	31,286	688	90,995	2,002	90,995	2,002	90,995	2,002	90,994	2,002
		Whole Current Three Phase GPRS/GSM	42,000	1,124	47	3,269	137	3,269	137	3,269	137	3,269	137
		LT CT operated GPRS/GSM	45,000	199	9	580	26	580	26	580	26	580	26
2	Tube wells & B-1	Whole Current Three Phase GPRS/GSM	42,000	41,650	1,749	65,441	2,749	5,458	229	5,458	229	5,458	229
3	MDC/MDM (Hardware + Software		75,000,000	-	101	-	10	-	10	-	10	-	
4	IT, furniture, Vehicles				52.37								
5	Installation	Single Phase GPRS/GSM			131.40								
		Whole Current Three Phase GPRS/GSM			303.69								
		LT CT operated GPRS/GSM			4.47								

Total CAPEX				74,260	3,087	160,285	4,924	100,302	2,405	100,302	2,405	100,301	2,394
OPEX													
5	Communication Cost, Licensing Fee etc. (New Procurement as per UDIL Specs)		840	78,010	66	161,045	135	101,062	85	101,062	85	101,061	85
6	Communication cost, licensing fee etc. (Existing AMR meters)		600	12,500	8	12,500	8	12,500	8	12,500	8	12,500	8
7	Replacement of Defective AMR meters against already existing AMR meters	*Single Phase GPRS/GSM	22,000	2,750	61	500	11	500	11	500	11	500	11
		*Whole Current Three Phase GPRS/GSM	42,000	600	25	200	8	200	8	200	8	200	8
		*LT CT operated GPRS/GSM	45,000	400	18	60	3	60	3	60	3	60	3
8	Staff Salaries, Office Rent				69		69		69		69		69
Total CAPEX*				246		234		183		183		183	
Total CAPEX and OPEX				3,332		5,157		2,588		2,588		2,578	
***Assuming a defective rate of 7% + new connections**													

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