PRIED
Policy Research Institute
for Equitable Development

# Fostering Solar PV in high-loss Feeders: Mapping Solutions

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# Preface

Sustainable Development Goal 7 (SDG 7) aims to ensure "access to affordable, reliable, sustainable and modern energy for all". Since Pakistan has affirmed its commitment to achieving SDG 7 targets by 2030, it needs to double its current rate of change to do that. A major obstacle in its way is the fact that its power sector is beset by significant transmission and distribution losses and cost collection problems. Together, these cost the national exchequer billions of rupees in annual losses.

The distribution system, indeed, has been the Achilles' heel of the power sector since long. Over the decades, it has not just incurred huge losses consistently, it has also made the national grid very fragile both technically and financially. Either improving or replacing it, therefore, is a pre-requisite to start and promote a sustainable change in Pakistan's power sector.  But an often-ignored idea in Pakistan's energy discourse is how an optimal replacement of a leaky transmission and distribution system with distributed generation (DG) applications such as solar photovoltaic (PV) can both cut costs (by minimizing the expense on laying long transmission lines) and reduce the incidence of line losses (by decreasing the need for transmission lines in the first place). By generating electricity close to end users, these applications also have the potential to decrease the need for transformer and transmission line upgrades, extend equipment maintenance intervals and improve the distribution system's reliability. In other words, loss minimization, reliability, sustainable energy provision and clean and cheap energy—all could be achieved with a wellchosen Distributed Generation application.

Consequently, Distributed Generation is seen as a new but practical solution to the old problem of distribution losses. Putting it in place, however, needs a realistic action plan based on high stakeholder support, alignment of national and provincial electricity and energy policies and planning, a facilitative and enabling environment for investors and well-coordinated changes at each stage of the energy value chain.

Based on a 12-month research project, this report offers a clear roadmap for ensuring all these things. It points out the possibility of achieving the triple benefit of reducing line losses, improving reliability of power supply and accelerating renewable energy advancement by solarizing high loss feeders. Given its meticulously carried out research and its people-centric approach, I expect it to be a useful resource for policymakers intending to achieve the above-mentioned changes in the power sector. I also hope that it will soon find its way into the national debate on developing an enabling policy and regulatory framework for solarizing high-loss feeders.

This report, though, could not have been possible without an unstinting support from the K-Electric which generously shared its very useful grassroots level data with PRIED. I cannot thank its management enough for its invaluable help and assistance in this regard.

Muhammad Badar Alam
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# List of Abbreviations

| | |
|---|---|
| SDG | Sustainable Development Goal |
| T&D | Transmission and Distribution |
| DGD | istributed Generation |
| PV | Photovoltaic |
| DSPV | Distributed Solar PV |
| PPP | Public-private partnership |
| RE | Renewable Energy |
| DISCO | Distribution Company |
| NEPRA | National Electric Power Regulatory Authority |
| KE | K-Electric |
| PESCO | Peshawar Electric Supply Company |
| TESCO | Tribal Electric Supply Company |
| IESCO | Islamabad Electric Supply Company |
| GEPCO | Gujranwala Electric Supply Company |
| LESCO | Lahore Electric Supply Company |
| FESCO | Faisalabad Electric Supply Company |
| MEPCO | Multan Electric Supply Company |
| HESCO | Hyderabad Electric Supply Company |
| SEPCO | Sukkur Electric Supply Company |
| QESCO | Quetta Electric Supply Company |
| AT&C | Aggregated Technical & Commercial Losses |
| SSGC | Sui Southern Gas Company |

| | |
|---|---|
| CPPA-G | Central Power Purchasing Agency |
| IFC | International Finance Cooperation |
| UPS | Uninterrupted Power Supply |
| DSM | Demand Side Management |
| IPPs | Independent Power Plants |
| RPO | Renewable Energy Purchase Obligation |
| kW | Kilowatt |
| MW | Megawatt |
| GW | Gigawatt |
| kW | hkilowatt hours |
| GWh | Gigawatt Hours |
| TWh | Terawatt Hours |
| IDCOL | Infrastructure Development Company Limited |
| CAPEX | Capital Expenditure |
| OPEX | Operational Expenditure |
| EPC | Energy Procurement & Construction |
| PPA | Power Purchase Agreement |
| SPI | Solar Power Inc. |
| AMI | Advanced Metering Infrastructure |
| CST | Community Solar Tariff |
| FiT | Feed in Tariff |
| TOU | Time of Use |
| ToD | Time of Day |
| O&M | Operation & Maintenance |

# Executive Summary

Solarizing high-loss feeders offer a potent option for a reliable, affordable, sustainable and climate-safe energy system. The current status of overall T&D losses and sustainable energy access paint a very bleak picture across the country. An optimal strategy promoting targeting distributed generation growth in the high-loss areas builds a compelling case for Pakistan. It particularly provides three key major advantages: renewable energy uptake, reducing distribution losses and finally providing uninterrupted supply to end-users

Optimal Solar PV placement would require targeted financial instruments and business model solutions. Innovative market-oriented finance and business models are emerging as a powerful tool to stimulate decentralized solar drive. However, experience indicates that decentralized power sector solutions are largely tailor-made—designed and executed as per local conditions and to accommodate the energy needs of the targeted community. This warrants more attention to the design of 'strategic fit' regarding sustainable uptake of solar PV in high loss zones

Conceptualization of drivers and barriers restricting the uptake of solar PV is crucial for formulating optimal business model. Our study ascertains (a) Solar energy is all around us and it has already reached grid parity and so is one of the most economic source of energy procurement, (b) Interrupted power supply and other supplementary self-reinforcing forces and synergies including free rooftop spaces, rising electricity bills—has created strong demand forces for solar PV adoption, (c) However high cost of technology and absence of a facilitative and supportive policies have constrained solar PV diffusion, (d) The potential of business models in stimulating solar PV uptake therefore seems undisputed.

The existing host-owned models will fail in solarizing high-loss areas. Corporate sector and community engagement and mobilization will be the bedrock of this solarization drive, this would require a more holistic intervention approach in terms of putting in place necessary regulations and facilitative environment to allow for changes on the ground. This is important as the electricity markets in the country are heavily regulated especially when concerning the operations of DISCOs. Two potential ownership model could be third-part solar, and public private partnership between a utility and third-party investor. Whereas community solar in the form of distributed generation on a high loss feeder can also serve the load demand of the community on an immediate basis, while providing affordable, clean, and reliable energy supply

# Chapter 1

## 1.1. Overview

The lack of access to reliable, affordable, and clean energy, the high electricity demand for national socioeconomic transformation visions, and the 2030 Agenda for sustainable development has caused interests in the pursuit of sustainable pathways for meeting energy requirements. Pakistan is the fifth most populous country in the world with a fast-growing economy and rising electricity demand. Although today around 75% of the population has access to energy and the power deficiency has decreased sharply, yet the problem of unreliable power supply persists[1]. And so a large section of society still lacks access to reliable power supply despite recent progress in generation capacity. Fig. 1.1 presents a historic overview of average daily reported power outages/load shedding hours across all DISCOs in Pakistan. Except a few, majority of the DISCOs experienced multiple hours of power outages in last six years.

Power outages in high-loss feeders is one issue that has not received much attention. Although the endusers experience power cuts across the country, these power cuts are more widespread in regions characterized by high technical as well as non-technical losses. The interrupted power supply in these specific areas is primarily attributed to significant transmission and distribution (T&D) losses and bill collection problems. And so, despite availability of generation capacity and surplus energy, the utilities exercise a  hours of load shedding carried out in these regions. The two variables hence have a positive correlation.

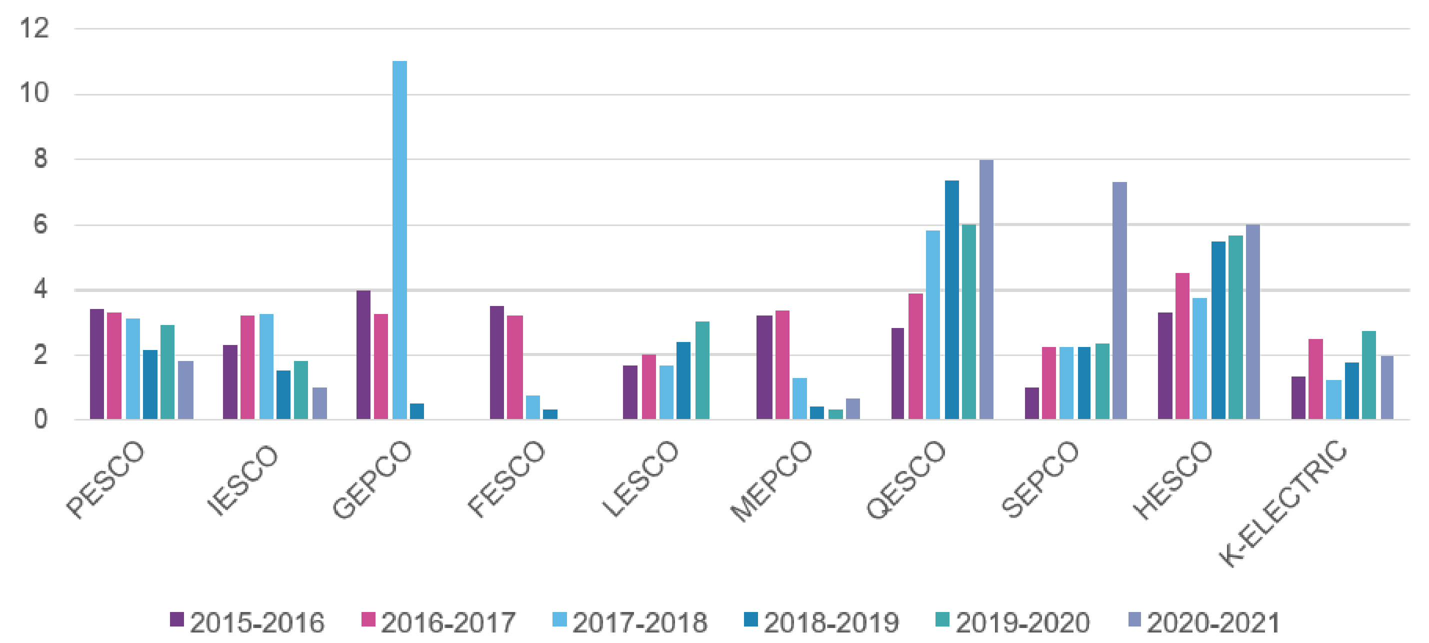


*Figure 1.1: Average Daily Load Shedding Hours Reported; Source: NEPRA PE Reports, 2015-2021*

1 World Health Organization. “Tracking SDG 7.” (2022).

Meanwhile, in the past, efforts have been made to turn around the distribution sector. A series of initiatives were launched by governments, to upgrade the distribution infrastructure and help the DISCOs improve their finances, as illustrated in Fig 1.2. Although the performance of DISCOs underwent strict check and balance after the inception of power regulator National Electric Power Regulatory Authority (NEPRA), but the loop holes in policies and governance let down DISCOs' performance. Every policy stipulates a set of standard parameters for every technical aspect like permissible voltage and frequency ranges, line losses, reliability index etc. as well as non-technical factors such as DISCOs expected recovery ratio, billing mech- anism, and maintenance of distribution system etc. Funds are attributed for upgradation of transmission and distribution infrastructure every year by NEPRA as well as in fiscal budgets (allotted to power sector). Every policy, whether it is National Power Policy (2013), National Electricity Policy (2021) or Grid code (2022), clearly defined the objective of infrastructure augmentation and reducing the line losses. Even the power sector improvement plans with the involvement of World Bank and private consulting firms, did not yield the desired results.

Privatization of DISCOs such as K-Electric (KE) in 2005 sought as a solution to the problem by increasing the generation capacity and improving the distribution grid through private investment. However, the current performance status of the KE shows that privatization alone is insufficient, if not backed up by strong reg- ulatory policies involving supporting mechanisms for the uptake of distributed generation by general masses. Furthermore, the reactive bureaucratic and entity level resistance has also contributed to incon- clusive results with regard to the planned initiatives, and we still see a very fragile power distribution sec-tor.

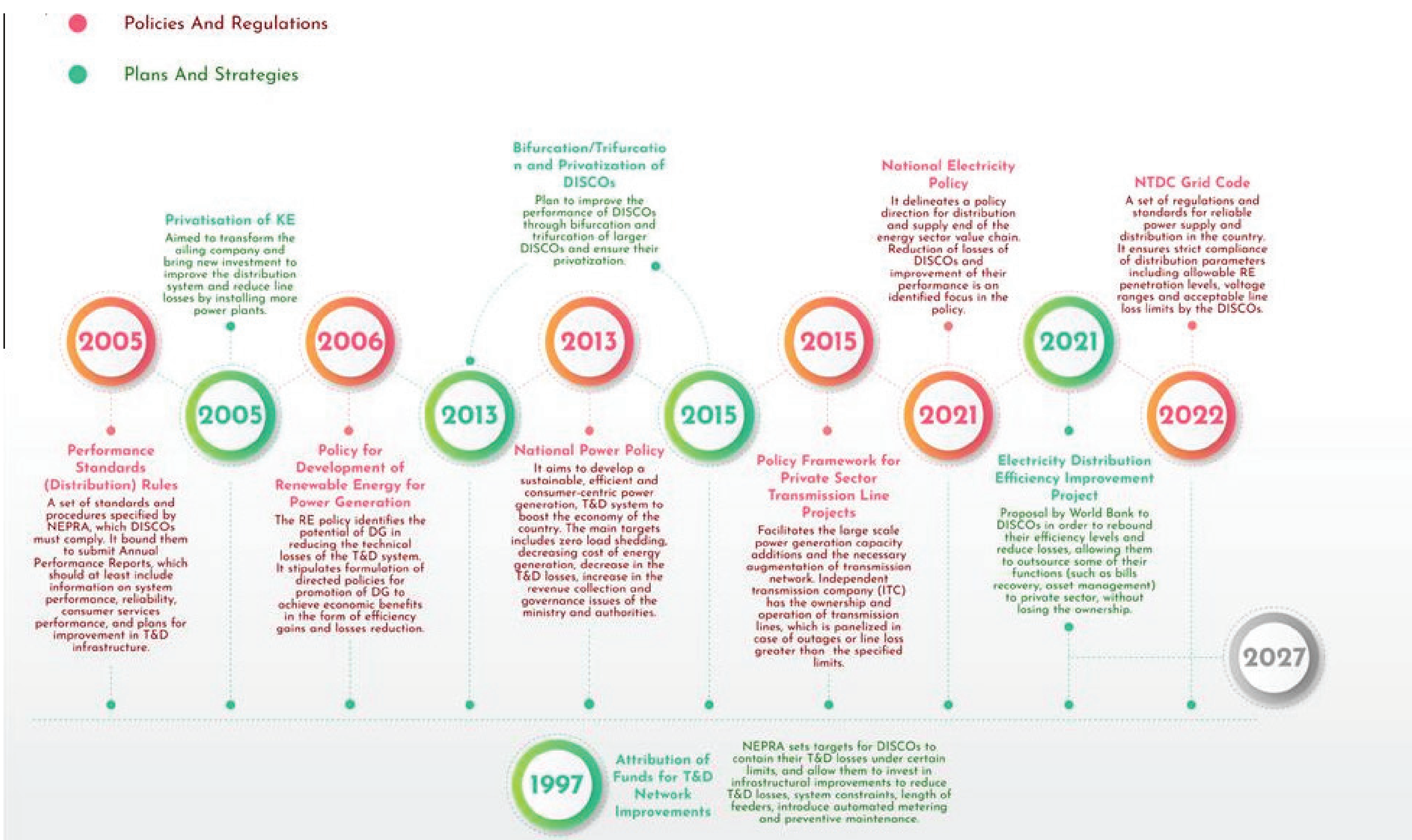


*Figure 1.2: Initiatives, Plans and Policies to Reduce Losses*

Access to affordable, reliable and sustainable energy is recognized as a basic human right. The distribution losses not only result in increased prices, but also as a part of the demand-side management policies, long hours of revenue-based load shedding are exercised, and the end-users have to put up with these power cuts. The indiscriminate load shedding by utilities at feeder level reflects their failure to address the longstanding challenge of excessive losses and taking action against the individuals involved in electricity theft. This consequently penalize all end-users in high-loss areas including the law-abiding citizens who make timely bill payments. Overall, this represents a significant challenge and has consequences to all sectors—specifically to high-loss configurations where these widespread inefficiencies make energy inac- cessible to specified social groups resulting in regional disparities and spatial injustices.

Strategically sited solar PV penetration in high-loss configurations offers an 'irresistible' and 'necessary' alternative to improve energy access (electrifying the last mile and improving reliable access to energy) and address the longstanding technical and inter-linked financial losses in the power sector. Solar PV is a mature technology and attractive in many ways. They let end-users meet part of their load from solar energy. End-users can either sell the excess to the utilities as well as other end-users. While net-metering regulations allowed on-site generation, however, so far, its growth is more concentrated in the 'compliant areas'—those regions with high recovery rates and relatively less technical losses. So, the diffusion of solar PV is not occurring uniformly in the compliant and non-compliant geographical configurations.

Based on this insight, this project builds on investigating the factors responsible for this skewed concen- tration to the proliferation of solar PV, while informing a suitable organization model—tailored to local dynamics for promoting DG penetration in high-loss areas. Overall, the study illustrates how key factors related to adopters restrict PV uptake in selected configurations, hence demonstrating the merits of insti- tuting a suitable organizational model for pushing DG—one that aligns the interests of all stakeholders and makes PV adoption more accessible and affordable. K-Electric was used as a case study for the surveys and analysis.

The rest of the report is structured as follows:

| | |
|---|---|
| **Chapter 1** | presents the context on distribution losses and lays out the objectives and methodology of the study. |
| **Chapter 2** | illustrates the survey results, applied to few selected feeders of K-Electric. |
| **Chapter 3** | presents alternatives for addressing the losses vis-a-vis unreliable access nexus, and potential business model solutions. Overall, it looks into the appropriateness of a sited-solar PV application—demon- strating its suitability and merits for loss-making areas in Pakistan. Considerable insight gained through expert interviews and a variety of international experiences is also used for general framing. |
| **Chapter4** | The recommendations are packaged in the Chapter 4. This last chapter is a synthesis of the case study findings, together with overall conclusions on how solar PV can be diffused jointly by relevant actors per- taining to different geographical areas. |

## 1.2. State of the Art

The power sector of Pakistan is beset by significant transmission and distribution (T&D) losses and bill collection problems—costing the national exchequer billions of losses annually. As of 2022, the T&D losses by the state-owned distribution companies (DISCOs) reached Rs. 110.4 billion, of which Rs. 71 billion were contributed by technical losses[2].

It is important to highlight here that power systems globally are inherently bounded with grid losses. How- ever, cross-country comparisons with Pakistan do not paint a very straightforward picture where the coun- try stands at the regional median of 20.3% with regard to grid losses. Fig. 1.3 gives a general picture on global line losses (% of output).

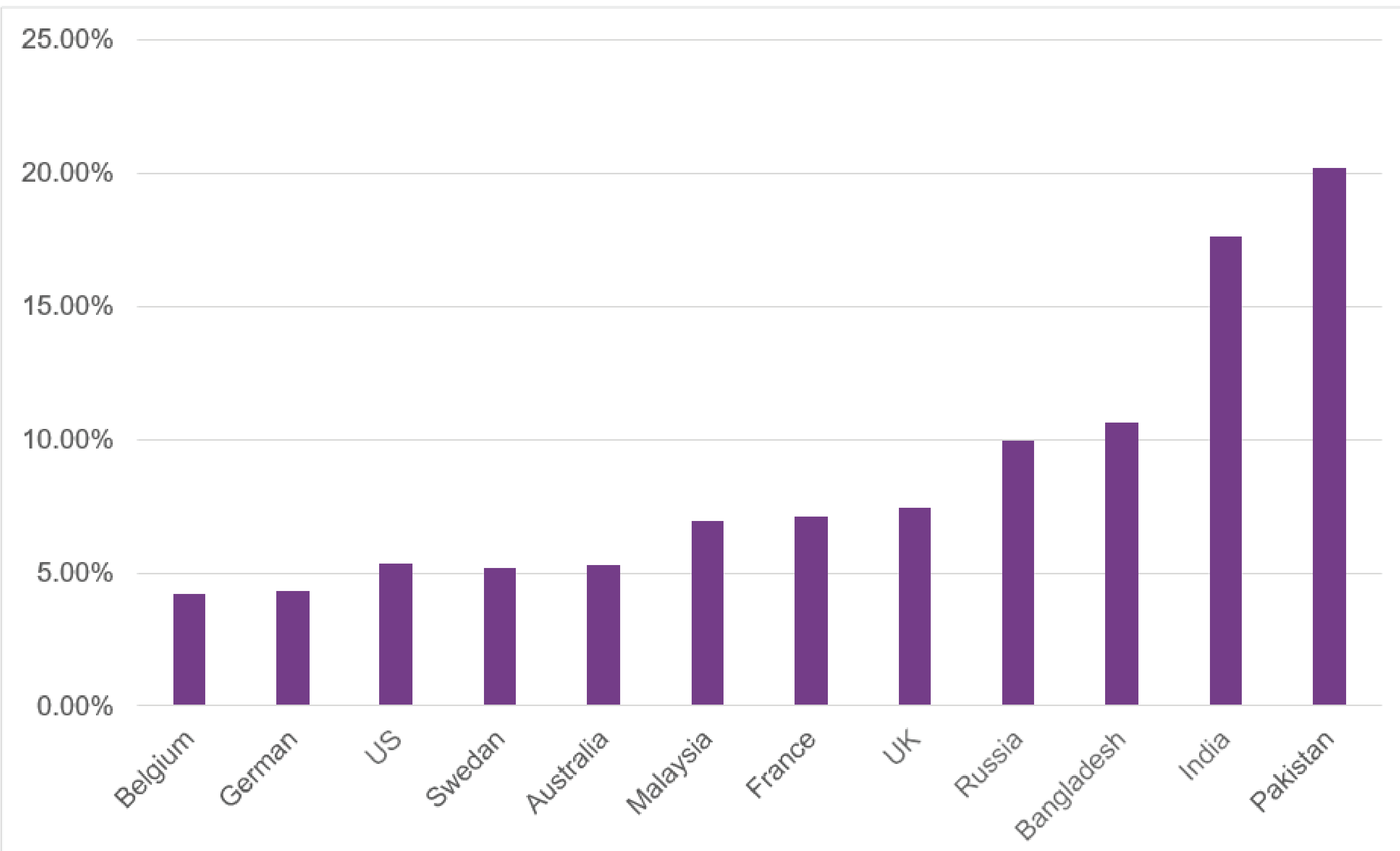


*Figure 1.3: Global line loss percentages FY 2019 (% of output); Source: World Bank, 2019*

In year 2020-2021, the technical losses suffered by DISCOs in Pakistan amounted to Rs. 71 billion, and the financial loss due to theft and low recovery reached Rs. 39.42 billion[3]. These losses in parallel have been significantly contributing to the Circular Debt—and has adversely affected the distribution companies' profitability and quality services from past several years. Fig 1.4 shows the average transmission and dis- tribution losses in the power sector since 2015; whereas Fig 1.5 shows the DISCO-wise losses in 2021.

2 NEPRA, "Power System Statistics 2020-21," State Ind. Rep. 2021, no. July, pp. 1–23, 2021

3 NEPRA, "Performance Evaluation Report." 2021

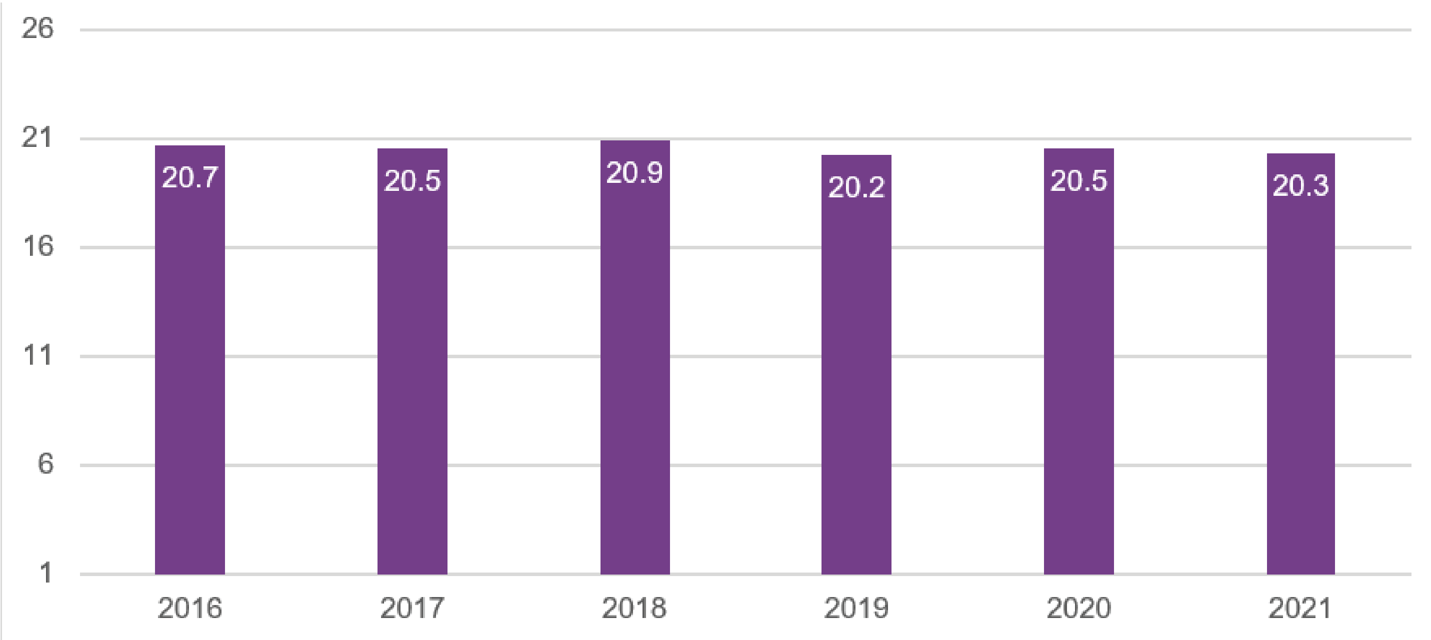


*Figure 1.4: Average T&D Losses; Source: State of Industry Report, 2021*

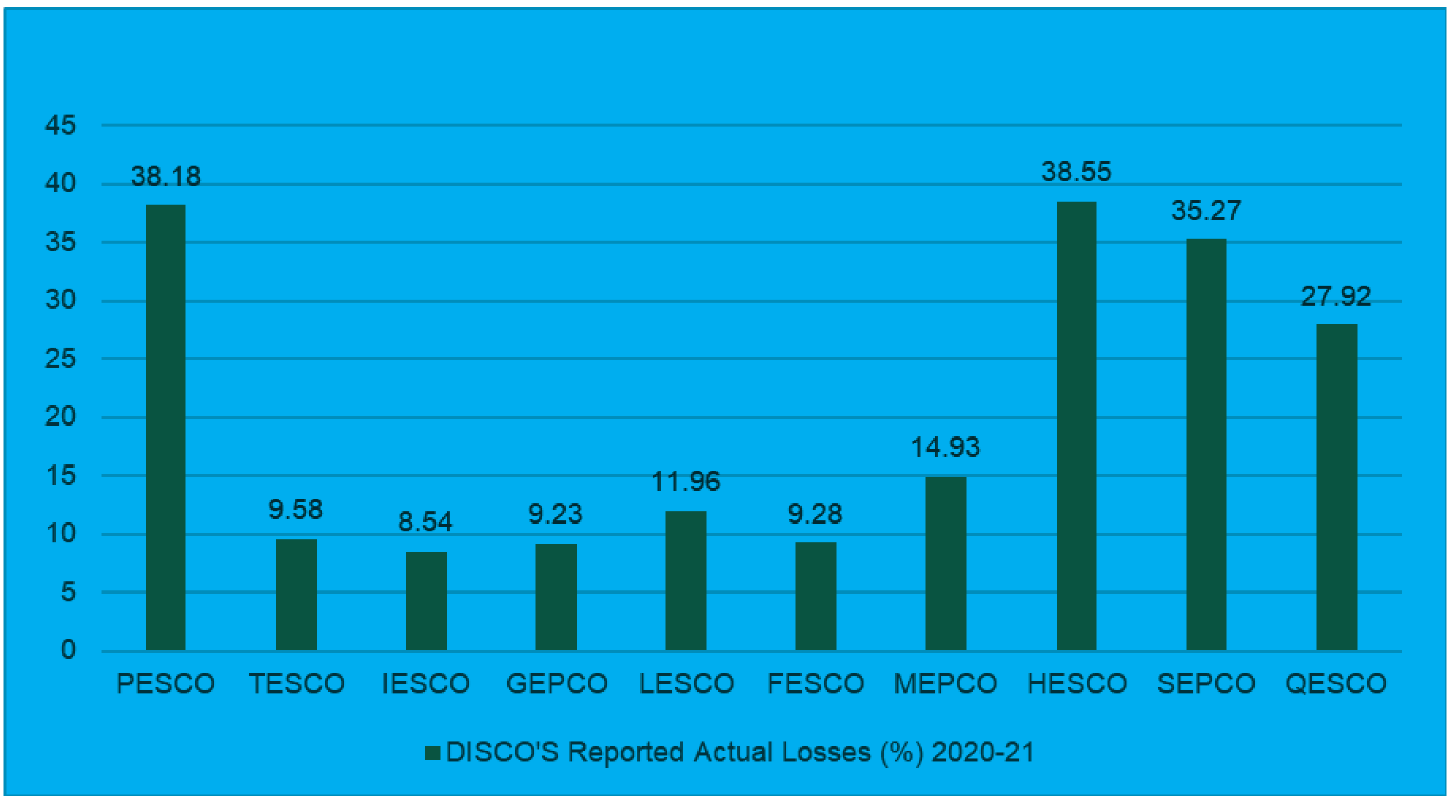


*Figure 1.5: DISCOs reported actual losses 2020-21; Source: State of Industry Report, 2021*

NEPRA has established T&D loss limits for each DISCO through consumer-end tariff evaluations. The DISCO is responsible for any losses that surpass the predetermined target losses. However, these tar-gets are persistently breached by majority utilities (see Fig 1.6). Despite all this, the government contin-ues to bailout distribution companies every year to keep them afloat.

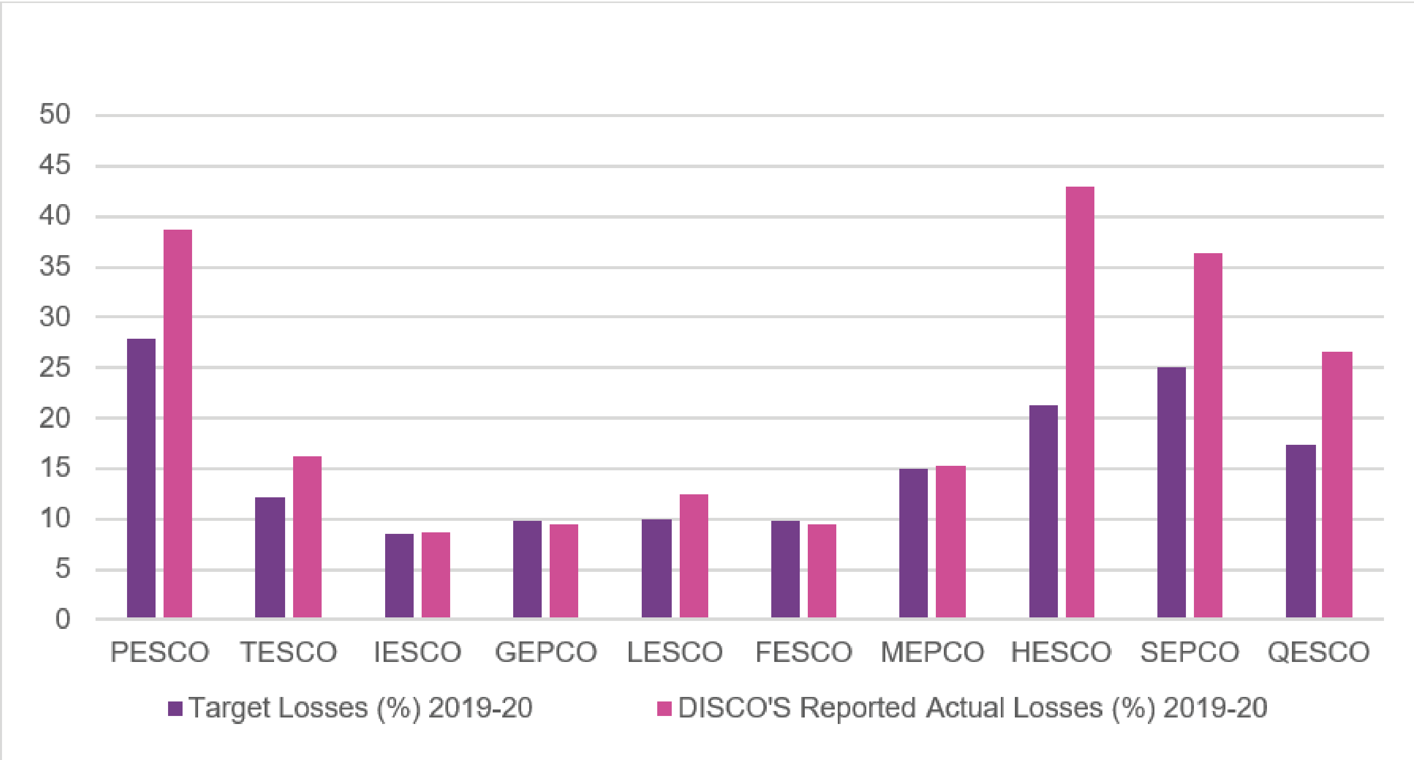


*Figure 1.6: Comparison of Targeted & reported losses; Source: State of Industry Report, 2021*

Most of the distribution companies in the country have T&D losses exceeding 15%, with the exception of four utilities namely FESCO, GEPCO, LESCO and IESCO. In 2019-20, PESCO had the highest loss rate of 38.9%, followed by SEPCO with 36.3%. In Punjab, all DISCOS have collection rates of over 94%. Howev-er, in the case of Sindh, Baluchistan and Khyber Pakhtunkhwa (KP), these percentages are relatively very low.  The financial costs associated with the imbalance in recovery ratio across all utilities is shown in Fig. 1.7 and Fig. 1.8

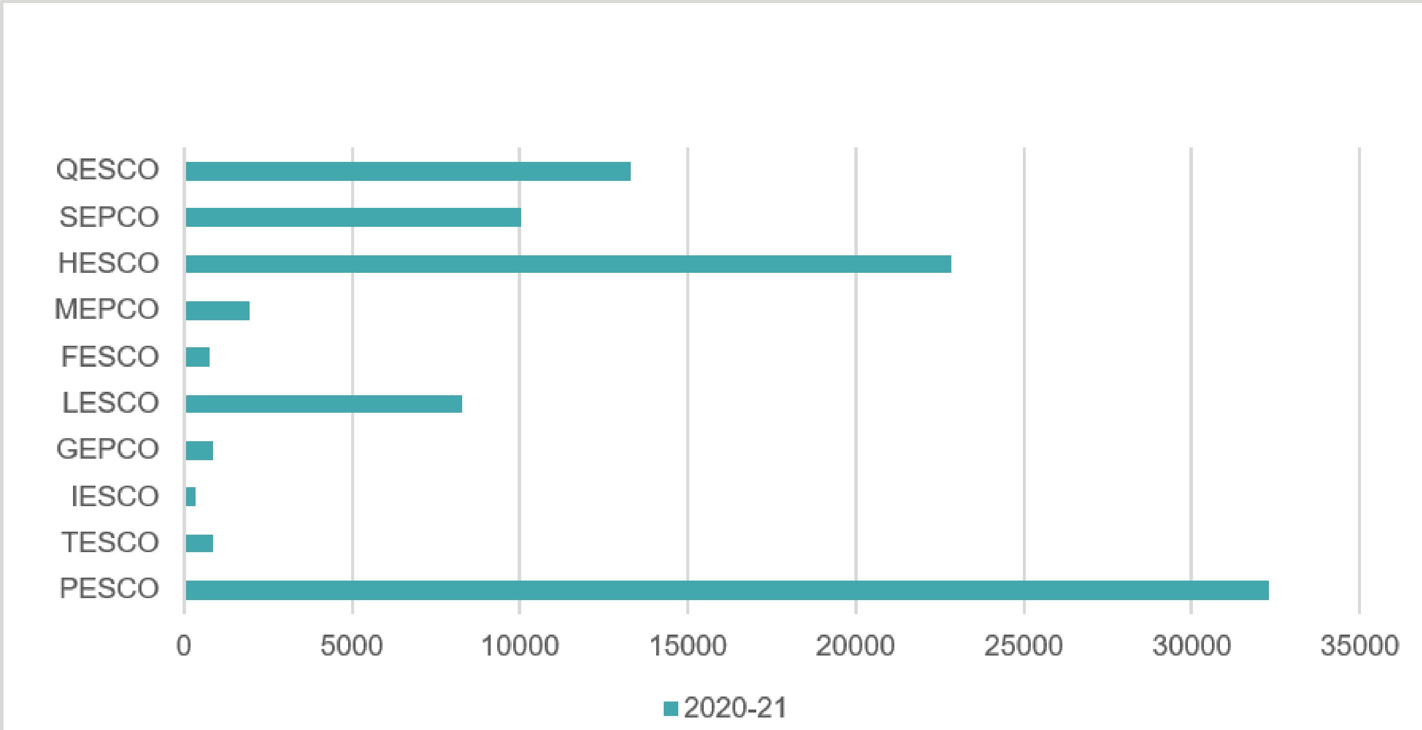


*Figure 1.7: Financial Costs of T&D Losses across Utilities, Source: State of Industry Report, 2021*

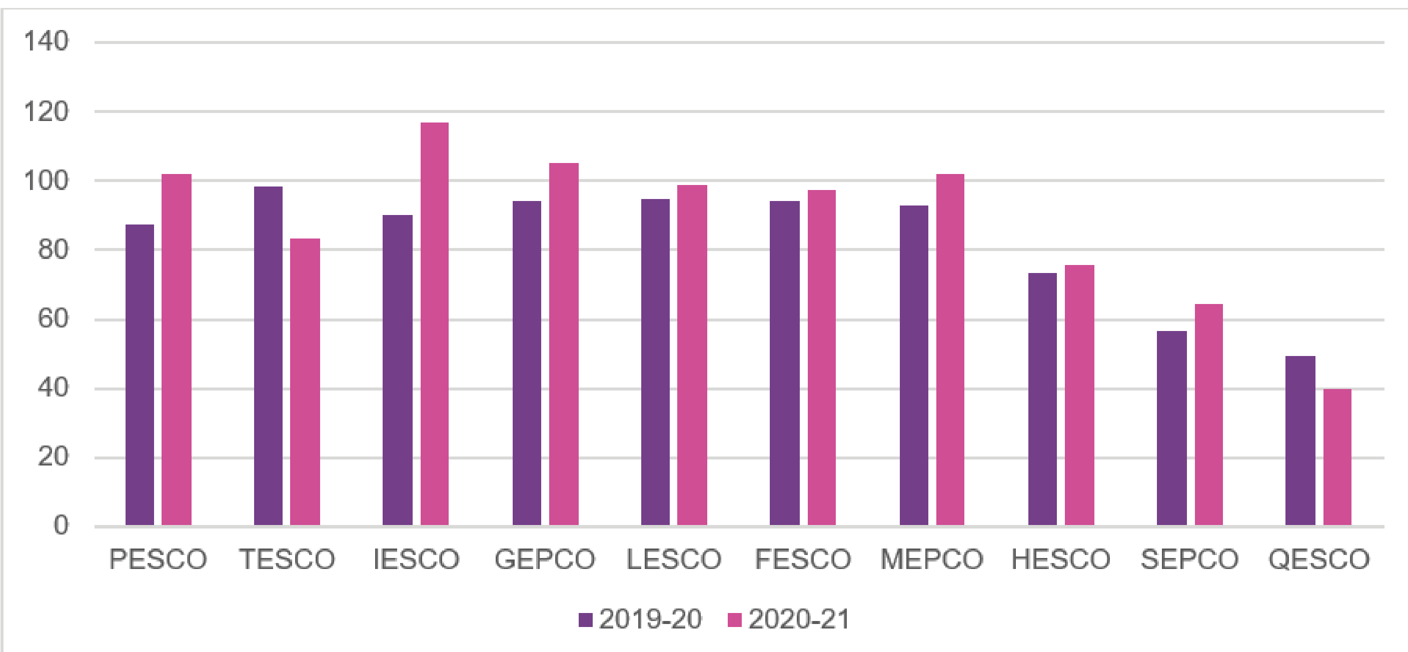


*Figure 1.8: Recoveries of Billed amount in DISCO; Source: State of Industry report, 2021*

## 1.3. Losses in K-Electric: A Quick Snapshot

KE was established in 1913 and has since been the sole electric utility that has powered Karachi—Pakistan's largest industrial hub—for over a century. This is the only vertically integrated power utility in Pakistan managing all key areas of generation, transmission, and distribution.

KE has an electrical network spanning across 6,500 square kilometers that supplies power to all resi-dential, commercial, industrial, and agricultural customers that fall under the city's ambit and beyond. It serves over 3.2 million customers across Karachi and districts of Sindh (Dhabeji and Gharo) and dis-tricts of Balochistan (Uthal, Vinder and Bela).

KE has been the pioneer of segmented load shedding in the country, where the company developed and implemented load shedding schedules based on the Aggregate Technical and Commercial losses on each feeder. This particular strategy has resulted in poor service to customers on high loss feeders ex-periencing unprecedented load shedding.

The recent upsurge of fuel prices has forced the company to cut down its power generation because of unavailability of funds for payments to Independent Power Producers and Sui Southern Gas. Custom-ers are also bearing the brunt of increased fuel prices in terms of excessive billings as well as load shedding of more than 12 hours.

During FY 2020-21, the KE system's basket price of electric power remained higher than the CPPA-G system. The cost-effective 'Take or Pay' generation capacity in the CPPA-G System was either unutilized or underutilized when KE was generating and/or purchasing electricity from higher-cost power plants in its generation fleet. Aside from other factors, an insufficient transmission system appears to be a major reason for KE's failure to purchase cheaper electricity from CPPA-G. The inadequacy of the transmission system between KE and the National Transmission and Dispatch Company Limited has been highlighted by NEPRA.

Similarly, average T&D Losses of the DISCOs and KE were recorded at ~21% and ~20%, respectively, in FY20. However, if we look at the feeder-wise losses, only 992 feeders experienced losses less than 20% in the year 2022. Remainder feeders are experiencing losses exceeding 20%. Around 348 feeders are facing losses between 20-40%, whereas 163 feeders are facing losses exceeding 40%. The Fig 1.9 illus-trates feeder-wise percentage losses.

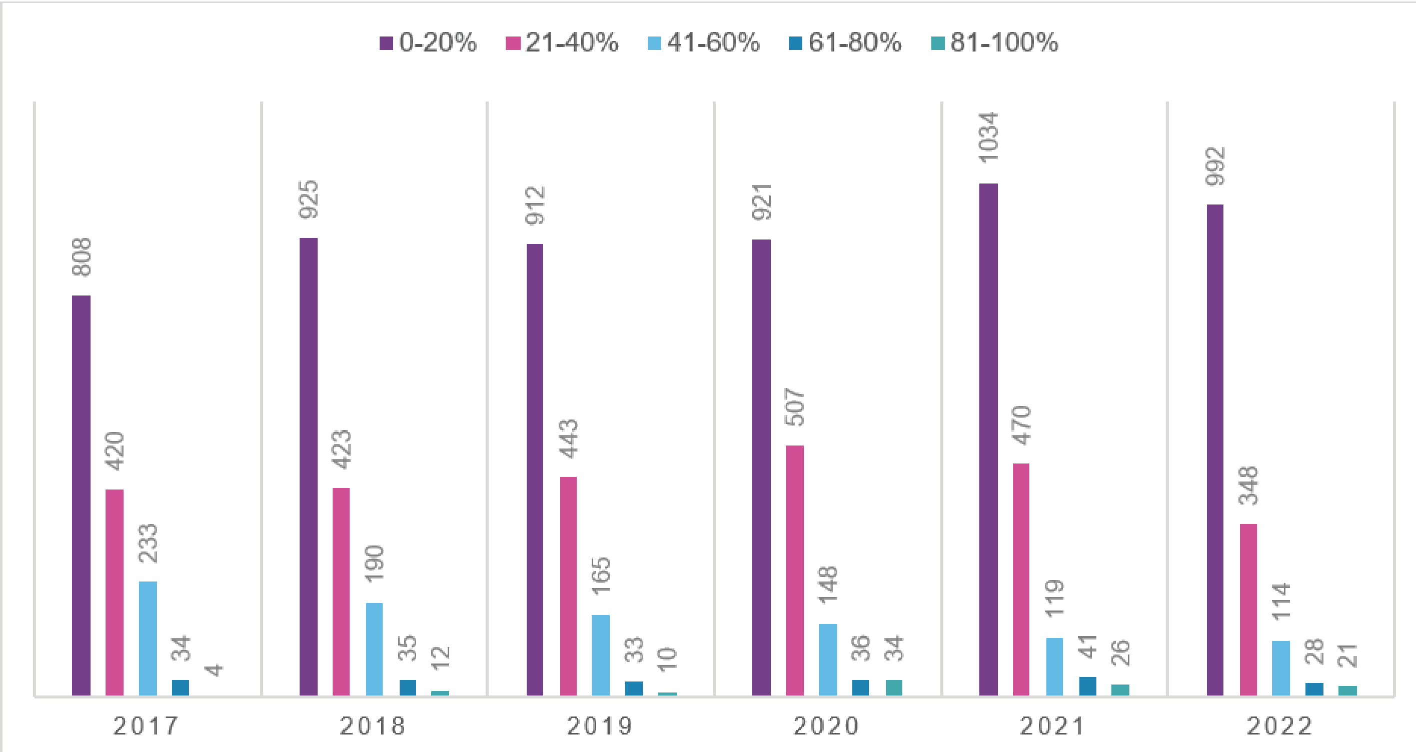


*Figure 1.9: KE Feeder-wise Distribution Losses, Compiled by author*

Similarly, there is a consistent difference between the number of units sent and the number of units billed over the years as shown in Fig 1.10. This difference attributes towards the aggregated technical and commercial losses (AT&C). Flawed expansion plans of the distribution system, long feeders with a very high low voltage line to high voltage line ratio, overloading and improper configuration of conduc-tor and commercial losses which encompass theft, pilferage and billing inaccuracies are the reasons that exacerbate the issue of feeder efficiencies and recoveries[4] .

4 M. Sharma, K. B. Kota, and T. Bhattacharjee, Advances in Sustainable Development, no. October 2021. Springer Singapore, 2022. doi: 10.1007/978-981-16-4400-9


*Figure 1.10: Energy Loss in KE Feeders; Source: NEPRA, State of Industry Report, 2021*

Now despite the ongoing problems of T&D, KE still managed to improve the recovery ratio from 92.1% in FY 2020 to 94.9% in FY 2021 as shown in Fig 1.11. Through streamlined instalment plans and strin-gent disconnection procedures, KE has attempted to empower consumers, reduce theft, and encourage timely bill payment. The encouraging factor is that with the increase in electricity generation and distri-bution, a rise in recovery ratio has also been witnessed. This is not only inducing confidence in the sys-tem but also addressing the electricity access issues.


*Figure 1.11: KE Billing Recovery Status; Source: NEPRA, State of Industry Report, 2021*

K-Electric's performance, however, has been relatively better on transmission and distribution losses on feeders as compared to the other DISCOs in the country, and the situation is much poorer in many other utilities. All this necessitates the need for reliable power supply and loss reduction strategy, if the end goal of sustainable power supply is to be achieved.

## 1.4. Objective & Methodology

The key objective of this study was to explore practical, sustainable and politically feasible approaches to possibilities of achieving the triple benefits of reducing losses, improving reliability of power supply and accelerating renewable energy advancement, through solarizing high loss feeders.

Socio-technical perspectives acknowledge that transition to new technologies is largely shaped by atti-tudes, actions, values, and beliefs of actors within a system. A co-evolving mix of societal factors, user practices, agency and power etc. determines the course of a transition. This emphasizes the role of incumbent actors including technology adopters, investors, policy makers, utilities, as well as financial intermediaries. So, we wanted to conceptualize the barriers and drivers restricting the deployment of solar PV in high loss areas and focus on the implications for a suitable business model solution on op-timal placement of DG in these configurations.

A multi-method approach that collects data at relevant points was used for the analysis. First relevant content was acquired through publications, annual reports, technical and commercial document.

Data was then collected in the form of surveys from the end users based in high loss configurations of K-Electric. Around 1450 households were surveyed from 76 high loss feeders—experiencing losses ex-ceeding 50%. The survey covered a range of issues concerning or other issues relevant to electricity failure, other sources to combat the energy crises, and their willingness and affordability to adopt the solar system. The data was collected between June-Aug 2022. Questions were orientated around the socio-economic status, current situation of the electricity bills, load shedding, awareness about solar technology, challenges/barriers restricting solar PV adoption as well as willingness for technology adop-tion. The information overall helped in assessing ground situation and assessment of a suitable organ-ize model for PV penetration in these localities.

For the pursuit of hospitable institutional/business models, which could provide the much needed ‘pro-tective space and enabling environment’ for cited PV growth in strategic areas, we conducted several interviews with utilities and energy experts. We also reviewed international literature and global prac-tices for the analysis on a suitable business model for PV penetration in high loss areas.

As there is no one-size-fits-all solution, but the optimal choice of measures needed to account for so-cio-economic conditions in context case-study. The information from the surveys was, hence, used to explore the ideal-fit. This study is expected to be relevant not only to KE but also several other utilities in the country.

# Chapter 2

## 2.1. Field Survey: High Loss Areas in K-Electric

The demand for decentralized configurations in Pakistan is already high due to the unreliable power supply. Frustrated with decade old injustices associated with centralised energy sector, residents in huge numbers have already switched to decentralised modes of energy generation. Some uneven statistics indicate that more than 68% of end-users alone in the country rely on alternative back-up energy systems (mostly UPS and fossil-fuel generators).[5]

Another study carried out by International Finance Corporation in 2015 also shows that an estimated $2.3 billion dollars are annually spent on alternative lighting alone in Pakistan. So, reliance tends to be more skewed toward low-cost and high carbon back-up appliances and solar PV has failed to take off in the region despite immense potential.

To understand local factors and pre-conditions, which could potentially drive solar PV uptake, we, there-fore, conducted important fact-finding surveys in the high-loss areas of K-electric. The surveys aimed to investigate the perceived/actual drivers and barriers that encourage or discourage end-users from installing a solar PV system. It also took into account the concerns of consumers regarding forced electricity outages, preferred alternate energy sources, willingness to adopt solar PV. These parameters gauged against the consumer’s socio-economic background, monthly electricity bills as well as their awareness about the solar PV technology. The survey findings were also used to inform a suitable business model on implementing planned roadmaps/models for driving DG solar in strategic areas.

## 2.2. Survey Results

For carrying out the surveys, feeder’s data under the jurisdiction of KE was used. For selecting the sample size, a two-stage sampling method was used (a) Random selection of 76 feeders (out of the total 101 feeders experiencing losses exceeding 50%); (b) After selecting the loss feeders, 22 and 18 households were randomly selected for surveys from each rural and urban sampling unit respectively– i.e., following the criteria of Pakistan Bureau of Statistics. 1450 households were surveyed from the jurisdiction of the 76 adjacent communities of the selected high-loss feeders.

5 Saleh, Naila, and Paul Upham. “Socio-technical Inertia: Understanding the Barriers to Distributed Generation in Pakistan.” Economics of Energy & Environmental Policy 11.1 (2022).

## 2.2.1. Socio-economic Status

The survey information shows that 95.66% households owned the dwellings where they were based. Also, houses are the common dwelling type in these jurisdictions. Further, around 57% of respondents are employed, 29% are self-employed, 5% are unemployed, 4% are retired, 3% are house-wives and around 1.5% are students. Most of the households mainly belong to the lower and lower-middle-income group, earning less than Rs. 40,000 – 32% of the sample household earns around Rs. 10,000 to Rs. 20,000 while 47% earns around Rs. 21,000 to Rs. 40,000. A 12% of households indicated earning around Rs. 41,000 to Rs. 60,000. Households in almost all the income groups (except the highest income group) claimed that it is difficult to live with their current income. The tabular representation of socio-economic status of respond-ents is given in Table 2.1.

| Residential Status | | |
|---|---|---|
| **Status** | **Frequency** | **Percent** |
| **Own** | **1387** | **95.7** |
| **Rented** | **36** | **2.5** |
| **Other** | **27** | **1.9** |
| **Type of Dwelling** | | |
| **Type** | **Frequency** | **Percent** |
| **Independent house** | **1368** | **94.3** |
| **Apartment or flat** | **29** | **2.0** |
| **Part of the large unit or portion** | **45** | **3.1** |
| **Other** | **8** | **.6** |
| **Current Living Status** | | |
| **Status** | **Frequency** | **Percent** |
| **Student** | **22** | **1.5** |
| **Employed** | **827** | **57.0** |
| **Self-employed** | **414** | **28.6** |
| **Unemployed** | **78** | **5.4** |
| **Retired** | **64** | **4.4** |
| **Housewife** | **45** | **3.1** |

| Monthly Household Income | | |
|---|---|---|
| Income group | Frequency | Percent |
| Less than 10,000 | 29 | 2.0 |
| 10,000-20,000 | 460 | 31.7 |
| 21,000-40,000 | 685 | 47.2 |
| 41,000-60,000 | 174 | 12.0 |
| 61,000-80,000 | 33 | 2.3 |
| 81,000 or above | 69 | 4.8 |
| **Monthly Household Expenditure** | | |
| Expenditure group | Frequency | Percent |
| Less than 10,000 | 37 | 2.6 |
| 10,000-20,000 | 445 | 30.7 |
| 21,000-40,000 | 642 | 44.3 |
| 41,000-60,000 | 219 | 15.1 |
| 61,000-80,000 | 37 | 2.6 |
| 81,000 or above | 70 | 4.8 |
| **Comfort level with current income** | | |
| Response | Frequency | Percent |
| Finding it very difficult to live on current income | 639 | 44.1 |
| Finding it difficult to live on current income | 271 | 18.7 |
| Coping on current income | 338 | 23.3 |
| Living comfortably on current income | 170 | 11.7 |
| Living very comfortably on current income | 32 | 2.2 |

*Table 2.1: Socio-economic status of respondents.*

## 2.2.2. Monthly Expenditure on Electricity Bills

Households have to spend a very high proportion of their income on electricity bills per month as shown in Fig. 2.1. Most of the households in surveyed areas spends Rs. 1000 to Rs. 3000 on account of electricity bills. Almost 24.1% households spend Rs. 4000 to Rs. 6000, while 3.1% spend more than Rs. 12000 on electricity bills in a month. To compare the electricity expenses with other monthly expenses of the household, it has been seen that in general, at least 10% of their monthly expenditure consists of electricity payments.

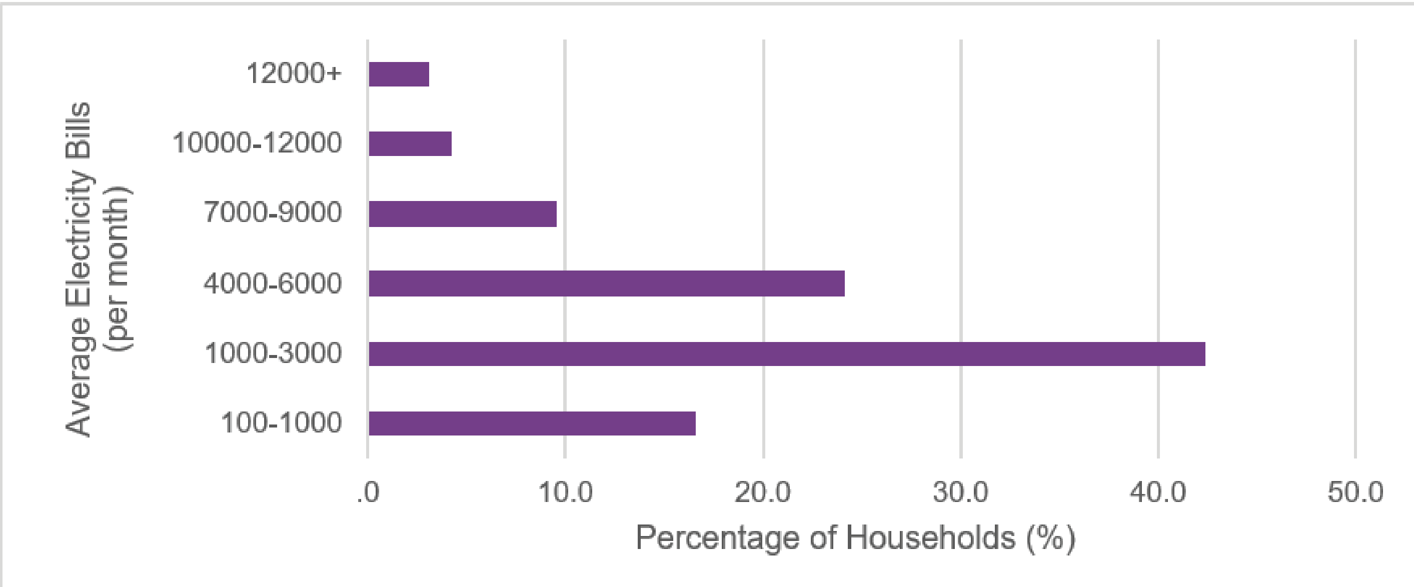


*Figure 2.1: Affordability of Electricity Bills*

## 2.2.3. Effect of Electricity Tariff Hike on Living Standard

The ever-increasing electricity tariff is one of the major factors that is motivating people to move to-wards low-cost reliable sources of energy. On average, 55% of the surveyed households claim that they have faced some sort of difficulty in paying their current electricity bill.

Almost 28.89% respondents said that they are paying more than Rs. 12,000 for electricity and it is very much difficult for them to pay such high bills. Among the respondents paying bills between Rs. 10,000-Rs. 12,000, 44.26% find it very difficult to pay the electricity charges while 11.5% of them find it slightly difficult. Even the 54.36% respondents paying less than Rs. 1,000, reported the difficulty in paying the bills, while 15.4% among them showed satisfactory response to their electricity bill (see Fig. 2.2).

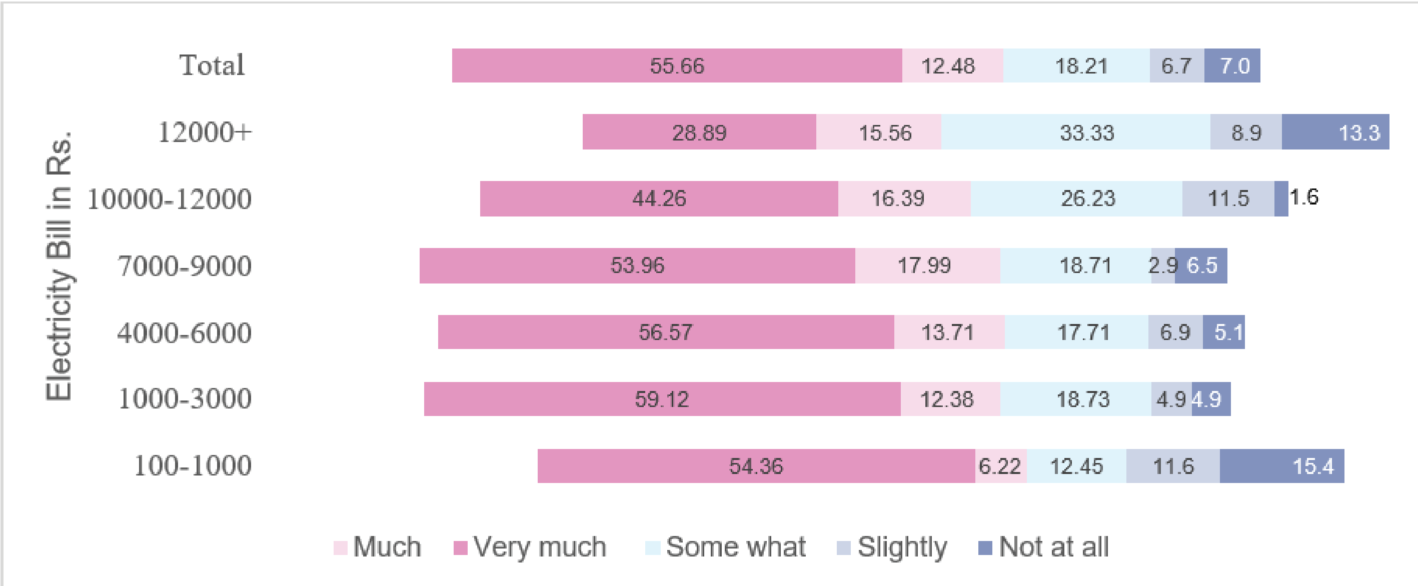


*Figure 2.2: Respondents having difficulty paying the electricity bills across different slabs of bill.*

## 2.2.3. Effects of Load Shedding on Daily Life

Though almost 98% of the households under study are facing load shedding, but the variation in hours of load shedding varies comprehensively. Households claimed that they are facing 7 to 11 hours of load shedding daily (see Fig. 2.3). Households also claimed that their lives are disturbed very much because of this prolonged electricity outages.

Consumers spending more than Rs. 12000 on electricity a month are also facing 7 to 8 hours of load shedding. These forced outages in the form of load shedding are significantly affecting people's life (see Fig. 2.4). In response to a question about the extent to which their life is affected by load shedding, 83.2% households strongly agreed.

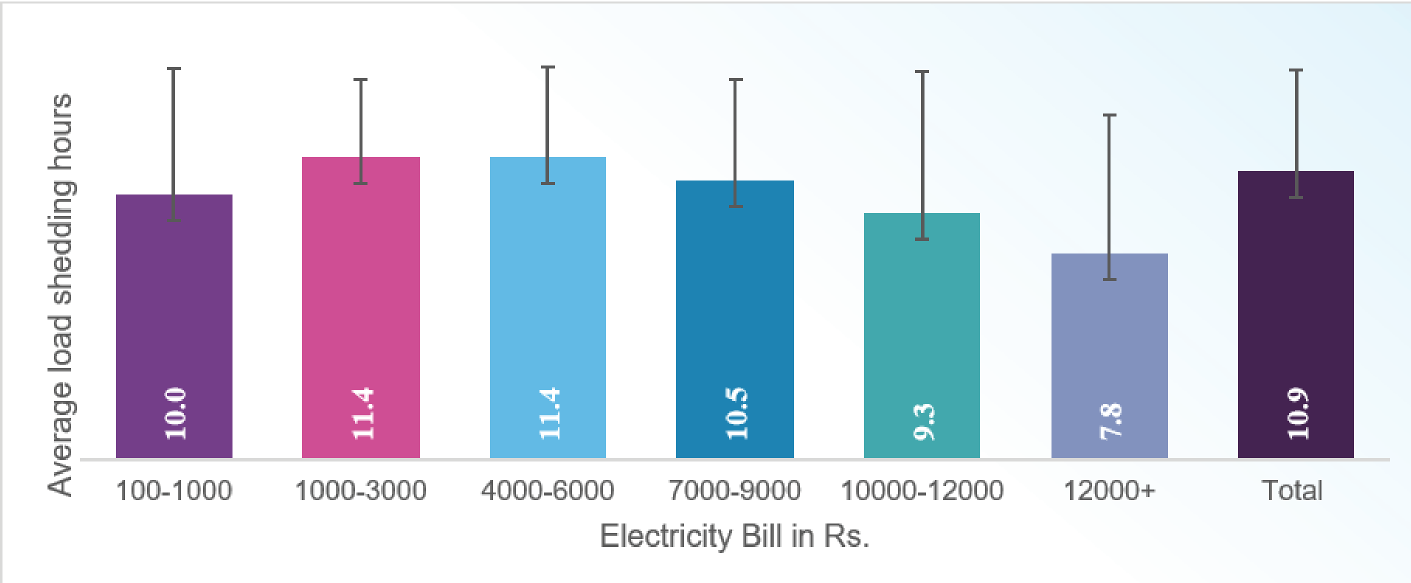


*Figure 2.3: Average load shedding hours vs electricity bills paid*

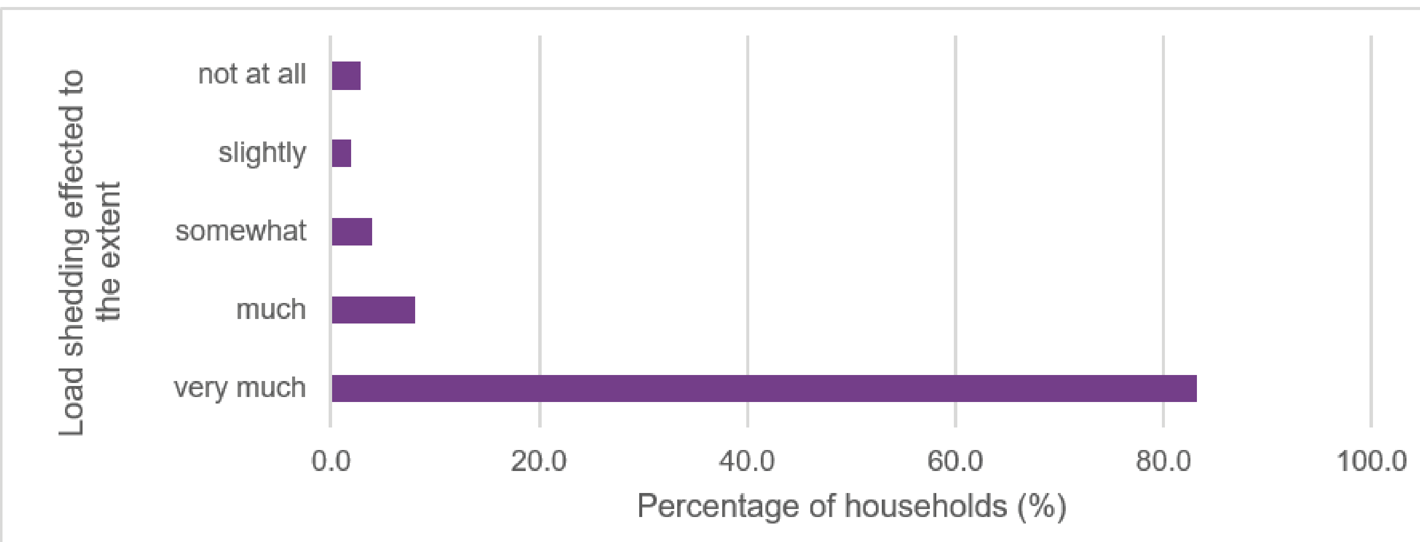


*Figure 2.4: Extent of load shedding effect on households*

## 2.2.4. Alternative Energy Back-ups

Around 29.4% of the households also indicated that they were relying on alternative energy back-ups for meeting their energy need, whereas the remainder 70.6 % had no energy back-ups. Fig. 2.5 further illustrates the distribution of these back-ups. For instance, 11.8% indicated reliance on solar systems, another 12.3% owned a generator, whereas 5.3 % of the respondents were using UPS as an energy back-up.

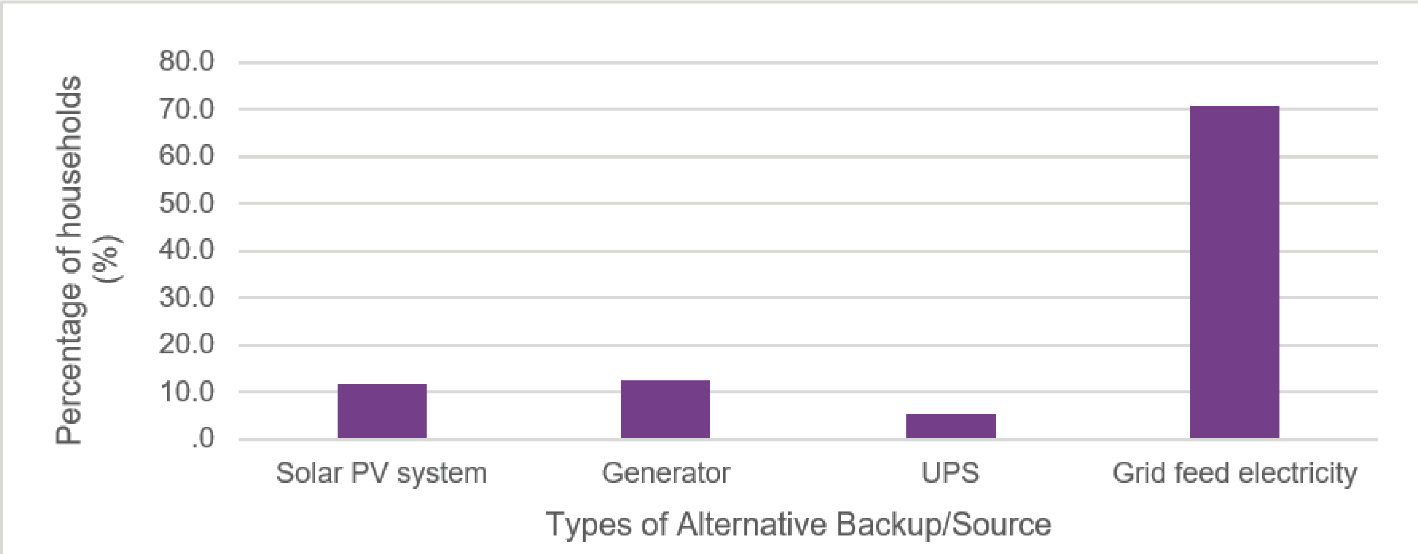


*Figure 2.5 Percentage and typology of alternative back-ups*

The results also illustrate that 98.8% of households that have installed solar along with grid electricity are owner-occupied. The respondents who already have a solar system installed were asked if the solar system was attached to a battery and grid. Fig. 2.6 shows that only a few households availed net-metering facility, whereas majority had these systems connected to battery.

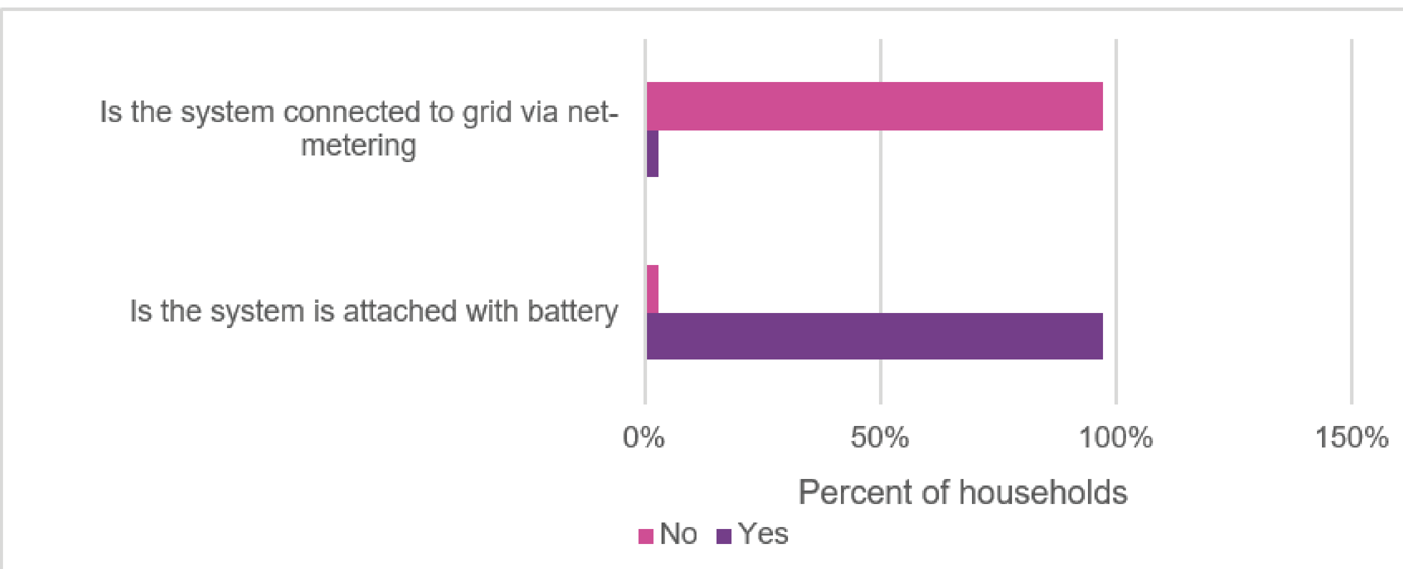


*Figure 2.6: Net-metering and battery backup status of installed solar system.*

## 2.2.5. Barriers to Adopt Solar PV System

The respondents were also asked to indicate on a scale of 1-5 (where 1 means not relevant and 5 indi-cate very relevant) the factors that discourage them from investing into rooftop solar. The distribution of the answer is shown in Fig. 2.7. Majority indicated that the high cost of technology, lack of support-ive policies, as well as limited access to finance were some of the key challenges restricting them to adopt the solar PV system.

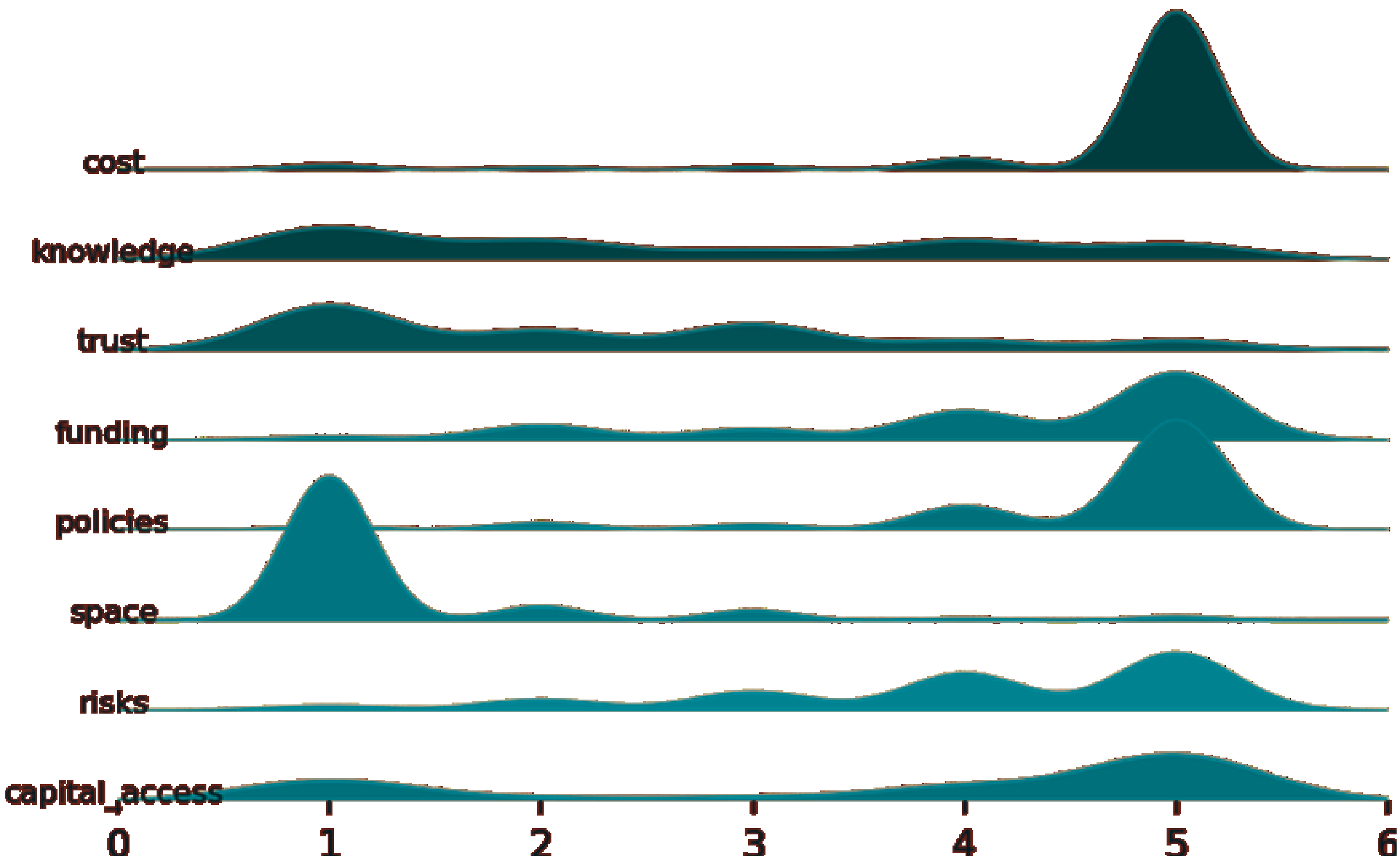


*Figure 2.7: Factors discouraging solar PV installation*

## 2.3.6. Lack of Solar Financing Knowledge

Upon enquiring about solar system financing scheme, 80.7% households stated that they self-financed the system, while 18.1% took informal loans. Only one household reported to borrow money from the bank, which indicates respondent's lack of information regarding solar financing.

## 2.2.7. Interest in Adopting Solar PV Technology

According to the survey, 43.25% of respondents indicated that they were very serious about solar PV adoption; 28.75% indicated that they were somewhat serious, while 17.17% said that they were indif-ferent. The remaining 10.9% stated that they did not consider adopting solar PV seriously (see Fig. 2.8).

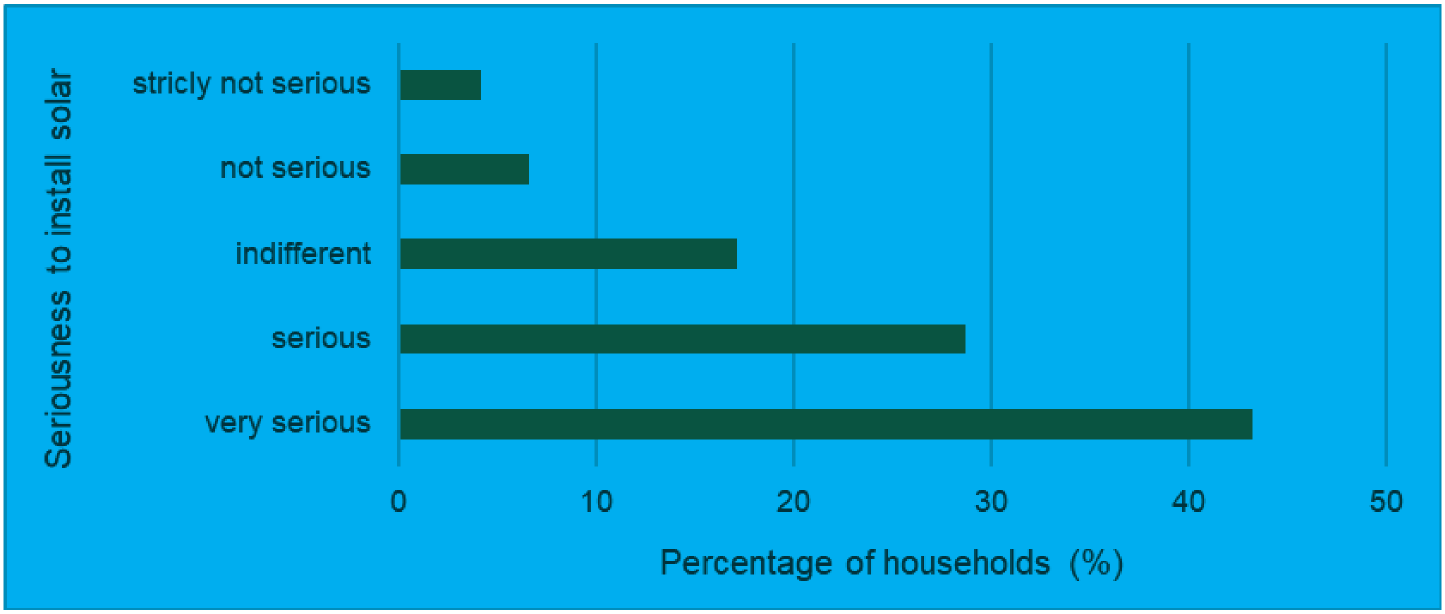


*Figure 2.8: Willingness and commitment of households to install solar system.*

## 2.2.8. Willingness to install solar PV in a facilitative envi-ronment

The survey also analysed the extent to which households would be interested to adopt solar PV if the government provides support in terms of loans or subsidies. According to the acquired data response, 21.2% households are willing to adopt solar if they are provided with subsidized technology, while 31.3% households indicated that they would be willing if the government provides loan.

Whereas, 24.3% households are skeptic to adopt solar even if the government provides loan, while 28.6% are skeptic even if they are provided with subsidized technology. 36.9% households indicated that they would still not be willing to install system even if provided subsidies, while 32% of them would choose not to go for solar even if government offers loans. (See Fig. 2.9)

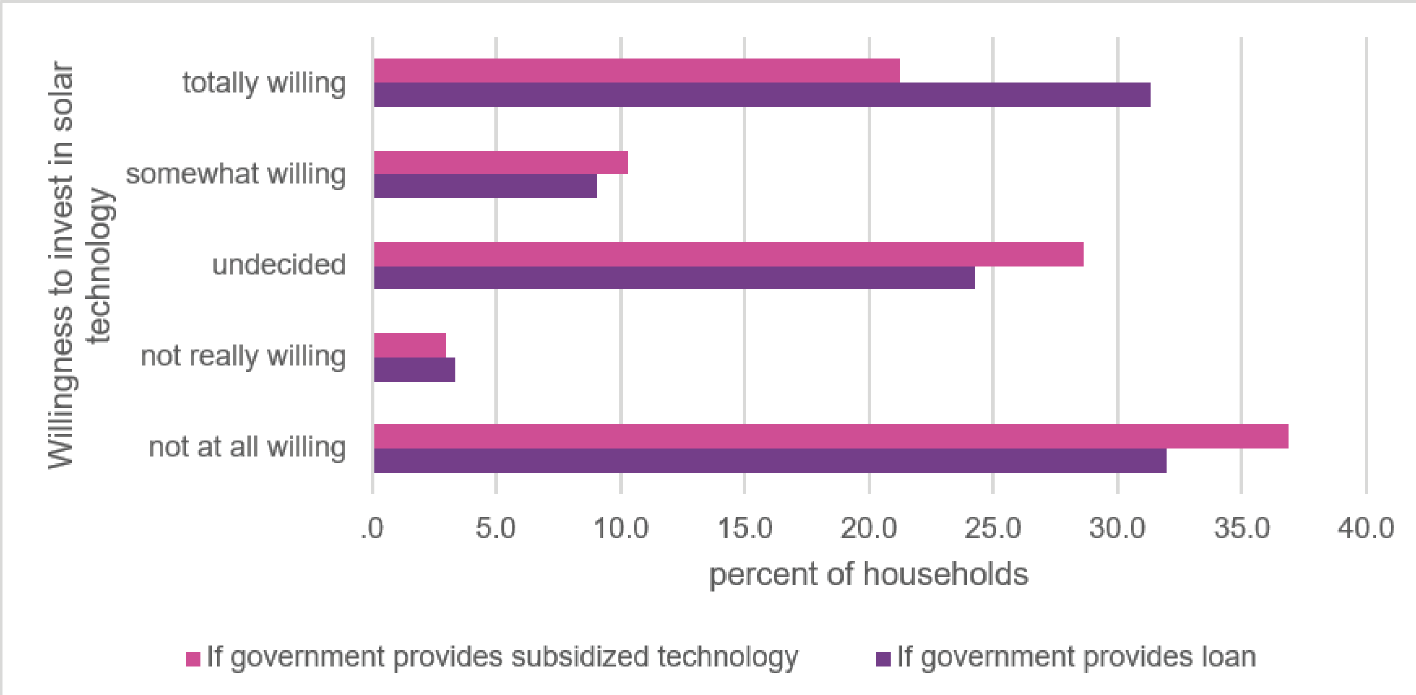


*Figure 2.9: Willingness to invest in solar technology if government facilitates in terms of either loan or subsidized technology.*

## 2.2.9. Factors Behind Non-willingness to Go Solar

The 25.5% of respondents who indicated that they are not willing to make an investment in install solar technology were inquired to explain their concerns. Around 37.7% households responded that they were not comfortable with the loan scheme. Other reasons that they indicated included inability to return loan, low income, affordable electricity bills, interest on loan, space reservations, consider solar as unnecessary etc. (see Fig. 2.10).

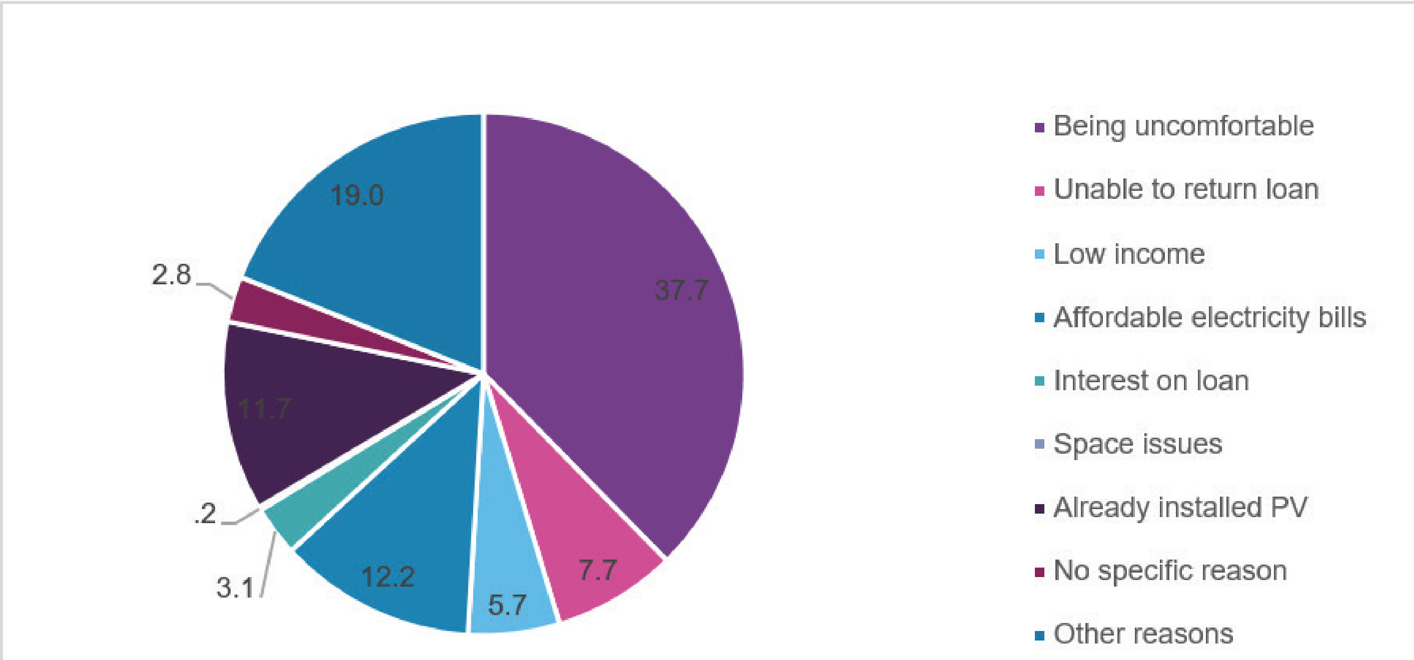


*Figure 2.10 : Factors behind  non-willingness to pay and adopt solar despite of loan scheme.*

When households were asked about the reason behind non-willingness in shifting to solar at subsided technology prices, the response was a mix. 30.6% of them cannot pay the rest of the amount in single transaction, and they need further discounts. Majority of them were not comfortable with this scenario and have financial constraints. Others consider it un-necessary while some do not trust on this scheme (see Fig. 2.11).

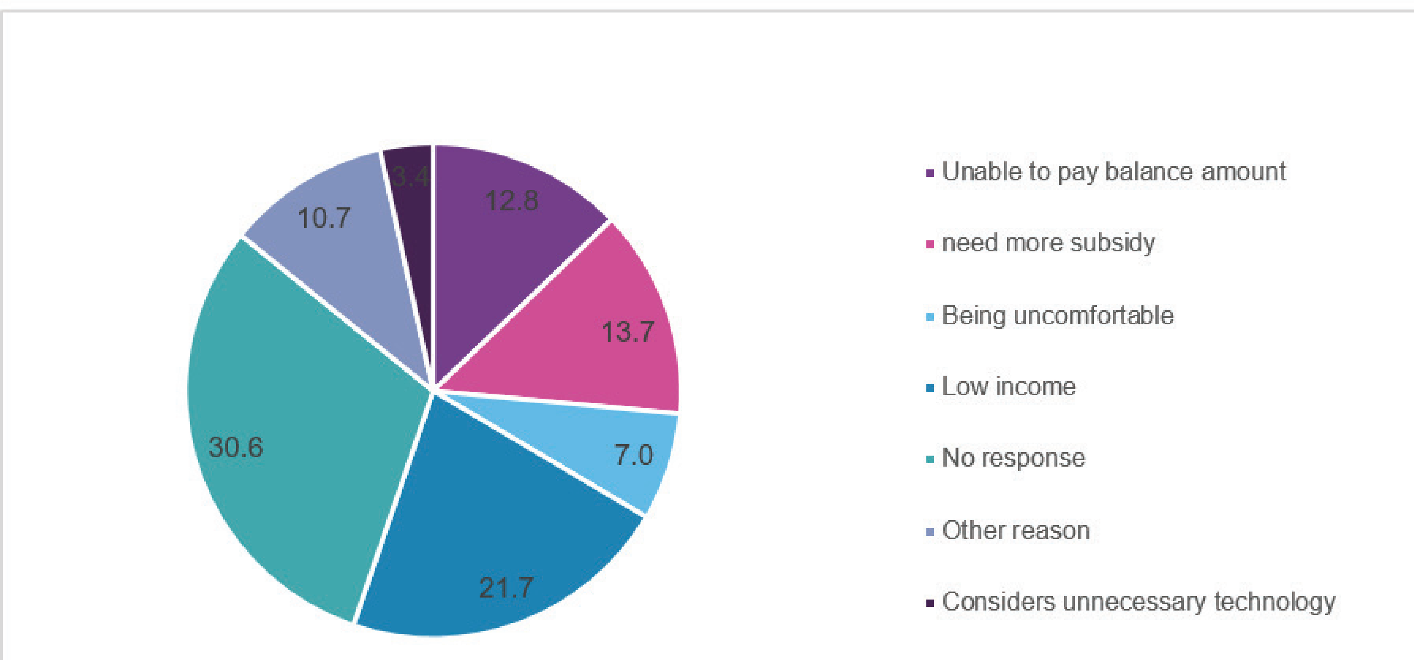


*Figure 2.11: Factors behind  non-willingness to pay and adopt solar despite of getting subsidize technology.*

## 2.3. Conclusion of Surveys

Currently residents in high loss areas are facing prolonged hours of load shedding in parallel with high electricity prices. This in general has pushed the desire for solar PV adoption as majority indicated strong interest for installing the technology.

However, high cost of technology among other factors continues to be a key deterrent—restricting so-lar PV diffusion as the majority households belong to the lower or lower-middle-income groups. Few households were still not interested in installing or willing to pay for the solar PV largely due to con-cerns with regard to non-availability of funds and absence of supportive and subsidized policies.

Overall, the key takeaway from the surveys was that given the context of socio-economic situation of people residing in high loss areas, it could be inferred that that despite strong interest to install solar PV, host-owned installations would not help in cited PV growth in the region. Hence, solarizing these areas would require thoughtful interventions business model solutions other than the existing host-owned model.

# Chapter 3

There is a double urgency to turn around the distribution sector from the inefficient equilibrium point. Solar power comes as a solution to reliable, affordable and adequate electricity supply. However, this needs a bold and contextually appropriate policy framework designed to local contexts.

In this chapter, we first analyze how and why solar PV can play a potential role in minimizing active losses in the grid. Further, the chapter also takes stock of suitable business models, which could stimu-late PV penetration overall but specifically in targeted regions. Several insights from international case studies as well as peer regional countries are used for a larger perspective.

## 3.1. Go Solar, Save Losses, Promote Reliable Supply: Novel Approach

A more economic and novel approach for reducing T&D losses is to change 'how and when' we use power. Optimal placement of solar PV applications could provide significant value to grid support. PV systems integration as distributed generation also provides better energy balance, improved systems economics, reduced costs and valued addition to both the customer and utility[6] . Solar PV technology has also been the preferred means to counter power blackouts, voltage variations and losses encoun-tered in commercial and domestic connections[7] .

These applications provide cost savings to utilities experiencing (T&D) system overloads and line losses. If the load is to be served by local generating sources such as solar PV near consumption points, this reduces the load. So overall solar-PV grid support can improve distribution system reliability as well as defer transformer and transmission line upgrades and equipment maintenance intervals. Distributed generation and targeted demand side management programs, offer electric utilities alternatives to large transmission and distribution (T&D) system capacity investments.

6 Sterling, J., McLaren, J., Taylor, M., & Cory, K. (2014). Treatment of solar generation in electric utility resource planning. Incorporating Solar Technologies in the Utility Resource Planning Process, (October), 1–72.

7 Chetty, A., Shoaib, M., & Sreedevi, A. (2014). An Overview of Distributed Generation. International Journal of Modern Engineeirng Research, 4(6), 41.

DG investments can also reduce a utility's variable costs and defer capacity investments. When proper-ly sited, both DG and DSM can relieve capacity constraints on the generation, transmission, and distri-bution systems and defer the need to build new facilities as well as reduce the utility's energy genera-tion requirements. Deploying distributed resources can result in both capacity and variable cost savings as well as capacity and variable costs[8] . The measures taken to decrease line losses always results in "loss savings"19

So, the primary two-fold advantage of DG solar penetration is (a) Energy loss savings i.e., savings real-ized by reducing load and resistance on the lines and (b) Capacity savings, realized by decreasing the need for capital upgrades via reducing peak loads on distribution, transmission, and generation system equipment. Overall, a higher renewable energy penetration level hence raises the likelihood of reduc-ing energy losses due to proximity of PV systems to load centers and thereby acts as a grid-support tool. By diffusing the PV system, we can reduce not only the line losses, but also increase grid resilience, lower generation costs and reduce requirements to invest in enhancing generation capacity, which re-sults in capacity saving of the power system infrastructure. Following the context, an optimal strategic approach targeting distributed generation growth in the non-compliant areas builds a compelling case for Pakistan. It particularly provides three key major advantages- encouraging renewable energy up-take, reducing distribution losses and providing uninterrupted supply to end-users.

The following section encompasses the case studies of countries that have successfully overturned the existing techno-economic imbalance in their power system by DG integration. The underlined business models and commercial models have also been charted out for addressing regional-centric impedi-ments that regional countries have faced leading up to DG insertion in overall grid infrastructure.

## 3.1.1. Sri Lanka – A Case Study of DG Impact on T&D Loss-es

Sri Lanka has set itself a target of attaining 100% of its energy needs from renewable energy (RE) re-sources by 2050. Being in a favorable geo-climatic location, the country has a multitude of RE options such as small hydro, wind, solar, biomass, etc. to replace its existing energy mix. On its road to achiev-ing a 100% RE mix and expediting the transition from fossil fuels, the technical framework in place en-courages RE-based DGs penetration in the existing distribution network. That is why RE-based DGs are quite widespread in Sri Lanka[9] .

A study was undertaken in analyzing the implication of DG penetration in four grid substations areas in Sri Lanka, namely Badulla, Rathnapura, Kiribathkumbura and Ukuwela. The DG installed capacity con-nected to these substations was 79.3 MW, which constitutes 27% of total DGs in the country. Different scenarios were analyzed based on the DG loading i.e., how much DG operated load is enough to have sustained financial savings in terms of T&D loss minimization. The conclusion details a direct proportion phenomenon between the DG penetration and financial savings concerning T&D losses minimization. With 40% DG loading, the saving amounts to LKR 807 million whereas, with 100% DG loading, the sav-ings sum up to LKR 2,271 million[10] .

8 Hoff, Thomas E.. "Identifying Distributed Generation and Demand Side Management Investment Opportunities." The Energy Journal 17 (1996): 89-105

9 M. Singh et al., "100% percent Electricity Generation through Renewable Energy by 2050: Assessment of Sri Lanka's Power Sector," p. 116, 2017

10 A. A. C. Priyangika, W. D. A. S. Wijayapala, and H. M. Wijekon Banda, "The impact of distributed generation on transmission and distribution losses in Sri Lankan power system," 1st Int. Conf. - EECon 2016 2016 Electr. Eng. Conf., pp. 54–58, 2017, doi: 10.1109/EECon.2016.7830935.

## 3.1.2. India – Case Study of DG Impact on Reducing Tech-nical Losses

The line losses in India are very high as compared to other countries i.e., 20%-40%. In the year 2021, the power sector incur a loss of 90,000 crore Indian rupees along with the debt of 67,917 crore Indian rupees. Power at distribution level is the weakest link in the supply chain of country's power system, due to poor infrastructure and operational inefficiencies. The line loss situation was aggravated to such an extent that the state of Arunachal Pradesh experienced aggregated transmission and dispatch loss (AT&C) of 56%, while the billing efficiency was 45%3. These losses hinder the investment opportunities that are required for improving the power quality, necessary for creating a renewable energy ready environment[11] .

During the last two decades, India has played a proactive role in overcoming this problem by incorpo-rating high volumes of RE generation. The adoption of RE has always been an important policy agenda in India. In Delhi, the involvement of private sector (including RE IPPs) at distribution level brought down the technical and commercial losses from 55% (in 2002) to 9% (in 2019)4. Among many, opera-tional reforms in India's states, the most noted one is separation of agricultural and non-agricultural feeders, with the encouragement of up taking the solar pumps. This significantly reduced the technical losses and energy procurement cost in these states. The distribution companies are mandated to meet the RE purchase obligations (RPOs) annually4.

Distribution companies balances supply and demand within their specified balancing areas as well as trades energy between regions to increase the energy flow efficiency. This helps to cope the intermit-tent nature of solar energy. Among many other line loss reduction initiatives, the Green Energy Corri-dor Programme supports the uptake of RE by upgrading the power lines. There are 14,000 microgrids and 20+ lac solar homes in rural and far fetch areas. In India, several physical and institutional reforms are initiated with an investment of 3,00,000 crore Indian rupees. It is expected that these reforms would open the pathways for grid modernization (smart grids) and new business models[12] .

## 3.1.3. Brazil – A Case Study of DG Impact on Reducing Non-Technical Losses and Resulted Savings

Brazil reached electrification rate of 99.5% in 2013. The balance between energy generation and utiliza-tion points out 20% losses with 116.3 TWh energy loss. Although Brazil belongs to an upper middle-income country, its line loss percentage is close to the line loss average of low-income countries. About 5% of the total incoming energy into the distribution grid is lost on the account of fraud and theft. This amount is sufficient to meet the energy needs of 7.9 million individual households5.

These non-technical losses generate high financial losses, overloading and degradation of the distribu-tion grid, and raised bills for consumers to compensate losses. In 2014, the monetarily value of these non-technical losses were more than 1.26 billion euros, while in 2017, they amounted to 2.3 billion euros5. The progress in PV system installation had transformed the consumers into prosumers and offered a great economic benefit for economically challenged communities.

The Brazilian Electricity Regulatory Agency (ANEEL) reported a case study that states the installation of 161 solar systems can generate almost 1 billion Euros in investment by 2023, while benefiting 130.5 million Euros to credit agents in the form of loan interests. The consumers could save 405 million euros in electricity bills. Most importantly, Brazil could save technical loss of about 185 GWh and the

11 P. Raman, J. Murali, D. Sakthivadivel, and V. S. Vigneswaran, "Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India," Renew. Sustain. Energy Rev., vol. 16, no. 5, pp. 3320–3325, 2012.

12 Prasanth Regy, R. Sarwal, C. Stranger, G. Fitzgerald, J. Ningthoujam, A. Gupta, N. Singh, " Turning Around the Power Distribution Sector: Learnings and Best Practices from Reforms," NITI Aayog, RMI, and RMI India, 2021.

social benefit will be job creation on 4000 citizens. PV systems has social benefits too, as it can lead to the creation of local co-operatives, earnings through net-metering, reduced maintenance of utilities, dis-couragement of illegal connections, while benefiting from the reliability and quality of energy supply[13] .

## 3.2. Suitable Business Model Solution

Owing to multiple failures surrounding centralized energy system in emerging economies—particularly load shedding and electrification gap—solar deployment has been emerging one of the most promising solutions to foster both clean energy transition and electrification. However, solar uptake in the broad-er region has been progressing at contradictory pace i.e., taking off in some regional countries, while remaining substantially slow in others largely owing to the emergence of facilitative business model solutions. Against the context, while potential of business models in stimulating decentralized solar deployment seems undisputed, there is no commonly used typology of business model, and its core characteristics vary from country to country and region to region.

### 3.2.1. Solar Business Model Variations

A good business model focuses at three key questions.

1. How to create value for a particular product?
2. Who are the customers?
3. How can this value be provided at an appropriate cost level?

The most crucial aspect of these models is that they are built around optimizing strategies that aim to best meet the needs of end users. Additionally, these business models give customers who might lack the financial means to install the technology—a significant barrier for developing nations—equal op-portunities. Therefore, new innovative institutional and business models offer the crucial "protective space and enabling environment" for the configuration and development of new technologies. Broadly, the solar business models are classified into three types: (a) Host-owned business model (also called dealer models); (b) community solar models; and (c) third-party ownership. The typology here has been discriminated based on who owns the installed technology.

In the host-owned/dealer model, the customer/owner themselves install the technology on their prop-erty.  In general, this is the most widespread and basic approach used for solar installation. A major drawback of this model is that it requires customers to pay upfront for the technology. And so overall this leads to its skewed concentration among resourceful sections of society. Also, it involves a high transaction cost for the installer since they have to handle challenges associated with seeking infor-mation, choice of suppliers, technological features and connection of system to the grid etc. Largely owing to these challenges, the dissemination of technology is very slow with host-owned installations.

To ease the high upfront costs challenge and other emerging barriers, different business models have hence evolved. For instance, the community solar model is based on shared ownership of the solar PV system among citizens forming a community. The electricity produced through the solar technology is either used by the community themselves or sold to the grid. A key advantage of this model is local land and community rooftop space which is used for technology installation. Further, it provides a cost-effective alternative enabling residents of a community to reduce installation cost via group purchasing and using renewable energy through virtual net-metering. These models, however, are still in early stages of development and research on its deployment is rare.

13 Baffi, Eduardo. Contributions to evaluate technical and economic benefits of distributed generation for low-income citizens. MS thesis. Universitat Politècnica de Catalunya, 2017.

In the third-party model, as the name denotes, a third-party actor both owns and control the system while siting it on a customer's roof. Payments are captured either through leasing, where the customer uses the equipment to produce and use the electricity, or through a power purchase agreement where the customer enters a long-term agreement to buy the produced electricity. The main advantage asso-ciated with this model is its simplicity. The customer is not required to pay for the technology upfront and there are additional benefits to consumers in terms of eliminating transaction cost linked with the complex regulatory and policy systems. These models also offer maintenance packages and perfor-mance guarantees, reducing the number of tasks and the risks for the customer. Third party models are currently widespread in many countries including US, China, Netherlands, Denmark, India etc.

### 3.2.2. Quick Insight from Peer Regional Countries

As stated earlier, if we look at solar business models in the broader region, the prevalence and design of these models vary across countries, and across regions within countries. Bangladesh is a leading example where coupling of the PV technology to a viable business model by 'Infrastructure Develop-ment Company Ltd' (IDCOL) resulted in its extensive uptake among customers—more than 9% of the country's total population—one of the highest shares globally. IDCOL is a public-private partnership initiative characterized by easy loans for the end-users, and highly standardized services in the entire value chain[14]. Likewise, in India, cumulative rooftop PV installed capacity surpassed 7GW in 2021, sup-ported by a mix of CAPEX and OPEX models facilitating dissemination of the technology. [15]

Stretching further the outlook, Taiwan introduced legislative reforms to adopt corporate power pur-chase agreements (CPPAs). One of the world's largest CPPA happened in Taiwan—Google's agreement to purchase 10 MW of solar energy to power its Changhua County data centre8. A CPPA permits the corporate entities to enter into the energy supply agreements directly with energy provid-er/generator. Currently, China is leading in solar energy growth by involving third-party business mod-els. This includes engineering, procurement and construction (EPC) model, community solar, hybrid PPA-lease model, Internet-based model like solar crowd-funding and Solar Power Inc. SPI Solarbao9. So, we could see that a new wave of supportive frameworks, business and finance models are playing an important role in fostering solar PV penetration and catalyzing the bottom-up transition.

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14 Heinemann, Georg, Raluca Dumitrescu, Christian von Hirschhausen, Noara kebir, and Daniel Philipp. "Lessons from deploying large-scale solar electrification in Bangladesh: Can the last mile become the first?" WIT Transactions on Ecology and the Environment 237 (2019): 75-86.

15 Mercom India Rooftop Solar Market Report Q4 & Annual 2021 – Executive Summary Form | Mercom India

8 Yeap, J. "Corporate PPAs: Asia-Pacific deployment market dependent" [WWW Document]. Pinsent Masons (2021). URL: https://www.pinsentmasons com/out-law/analysis/corporate-ppas-asia-pacific-market-dependent).

9 Zhang, S. "Innovative Business Models and Financing Mechanisms for Distributed Solar Photovoltaic (DSPV) Deployment in China", in Kimura, S., Y. Chang and Y. Li (eds.), Financing Renewable Energy Development in East Asia Summit Countries. ERIA Research Project Report 2014-27, Jakarta: ERIA, (2015): pp.161-191.

# Chapter 4

## 4.1. Conclusion and Policy Recommendations

This study ascertains that:

a. Solar energy is all around us and it has already reached grid parity and so is one of the most eco-nomic sources of energy procurement.
b. Interrupted power supply and other supplementary self-reinforcing forces and synergies, including free rooftop spaces and rising electricity bills—has created strong demand forces for solar PV adoption.
c. High cost of technology and absence of a facilitative and supportive policies have constrained solar PV diffusion.
d. The potential of business models in stimulating solar PV uptake, therefore, seems undisputed.

Pakistan is not only characterized by absence of such emerging models but also the current debate reflects very poorly on this 'absence' as the major preventing factor substantially slowing down the otherwise immense potential held by 'bottom-up energy transition' in the country. For any desired transition, a deep analysis is needed on how innovative business models could be aligned with broader bottom-up energy investment to ensure that solar PV uptake among communities is not further de-layed. Hence, for stimulating decentralized solar PV drive seems undisputed via framing a more contex-tualized 'business model' for cited PV penetration in strategic zones while keeping underlying barriers facing PV deployment in perspective would be imperative. Overall, the choice of context is very im-portant when framing an optimal business model solution. Any approach to change the status quo and promote cited PV growth should primarily acknowledge the following:

- Provide reliable, affordable and adequate electricity supply to end-users
- Provide value to electric utilities by reducing active power losses
- Provide value to overall power sector by reducing circular debt
- Increased use of clean and renewable energy
- Financial viability of investment
- More timely and quick intervention solution

Since corporate sector and community engagement and mobilization will be the bedrock of this solari-zation drive, this would require a more holistic intervention approach in terms of putting in place nec-essary regulations and facilitative environment to allow for changes on the ground. This is important as the electricity markets in the country are heavily regulated, especially when concerning the operations of DISCOs.

### 4.1.1. Potential Business Model Solutions

Our study findings illustrate that the existing host-owned models will fail in solarizing high-loss areas due to several challenges- importantly high upfront cost of technology, low customer awareness on financing channels, and poor access to financing. On the other hand, the demand forces for these sys-tems are very strong due to poor access to electricity, and prolonged hours of load shedding. Our sur-veys also illustrate that the key dwelling type in these areas is houses. Also, majority residents are own-ers of these dwellings. The strong demand forces for the technology as well as favorable dwelling land-scape hence make these regions attractive investment points. All this necessitates the need for planned and timely interventions for alternative business model solution.

Two potential ownership model could be third-part solar and public private partnership between a utility and third-party investor. Third-party solar could emerge as a potential commercial solution for solarizing high-loss feeders. In this model, the developer (third-party) installs the solar system on host-customers rooftop spaces. These systems are connected to the grid. The energy generated by these systems is then sold to the customer at rate typically lower than the grid provided electricity for a pre-determined period as agreed upon in the agreement. Furthermore, the third party is also responsible for operation and maintenance of these systems.

Another potential business model solution could be a public private partnership between utility and a private third-party entity. The private third-party could be invited by the DISCO to install solar power on consumer rooftops. Two possible ownership scenarios here would be:

a. Utility can entirely own these DG systems.
b. Utility could enter into an agreement with the third-party for mutual ownership and divide prof-its accordingly.

Furthermore, the third-party will be responsible for performing specific functions for example installa-tions, maintenance and operation of the systems as well as billing and revenue collection. The ad-vantages of this model include improved bankability, better management, and easy enforcement. Fur-ther, being an incumbent, it would be easier for the utility to arrange financing through linkages with public sector or international financial institutions. Finally, with direct engagement, the DISCO can max-imize several gains in terms of reducing losses, improving profits, and integrate new technologies, such as advanced metering infrastructure (AMI) and energy storages.

| **Business Model Solution** | |
|---|---|
| Third-Party Solar Model | Public Private Partnership |
| • Procurement: Utilities carry out initial available rooftop space; facilitate leasing mechanism<br>• Tariff scheme: Gross-metering at feeder levels. The tariff design should take into account installation, operation, and maintenance cost<br>• Financing: Dedicated lines of credit from national and international development banks which could aid in kick-starting in-vestment in this sector<br>• One window facility: Simplification of administrative and bureaucratic pro-cesses<br>• Payment: Proper security mechanism such as DISCOs responsible for billing | • Procurement: Aggregates roofs from con-sumers and carries out the initial site sur-vey from a contracted company<br>• Tariff: Power sold at regulated tariff<br>• Financing: Public-private co financing; concessional loans by public institutions for utilities<br>• Execution and operation: Utility build plants through contracted company, which also take care of operations.<br>• Payments: Bills collected by utilities busi-ness-as-usual or devolved to the third-party |

Community solar in the form of distributed generation on a high loss feeder can also serve the load demand of the community on immediate basis, while keeping them on the grid. In this model, the respective community also get cheap, reliable and continuous energy supply, thereby relieving them from stressful situation of load shedding and frequency deviations. There are currently two prominent community solar subscription models- one based on upfront capacity purchases ($/kW) and the other on no-money-down lease ($/kW-month) or power purchase agreement (PPA) ($/kWh) arrangements. Subscriptions are typically paid for in advance, and subscribers receive monthly bill credits for the amount of electricity produced by their share of the installation's capacity over a set time period (i.e., 20 years). Pay-as-you-go loan options are available from some utilities for this capacity purchase. In the latter model, customers contract to lease capacity or purchase energy from a portion of a community solar installation in exchange for a monthly fee.

Utilities or third-party project developers typically own typical community solar arrays. Its design starts with a shared solar array that generates and feeds solar power into the microgrid. Depending on the operational load and resource availability, the microgrid can be operated in islanded or grid-connected mode. The electricity generated by individual shares of community solar is then credited back to the participants' electricity bills, similar to how residential PV systems located on individual rooftops work.

To assist disadvantaged communities that would otherwise be unable to afford solar systems, the community solar tariff (CST) is charged at a 20% discount from the overall electricity tariff rates16. In some countries the Feed in Tariff (FiT) mechanism has also been practiced for exported units from community solar programs. In this framework, market responsive pricing, a production-based incentives and investment- based incentives are incorporated in order to bring down the payback period. Overall, FiT pricing are fixed and reviewed periodically. However, some incorporate the time of delivery of energy as well similar to time of use (TOU) metering systems.

### 4.1.2. Proper Tariff Structure and Metering Infrastructure

A viable tariff design plays an important part to encourage participation from potential project developers. Utilities can design tariff base for accurate price signals to customers, thus, assisting them in managing their load profile and temporal profile of solar resources, making it cost-effective. The "Time of day (ToD)" tariff scheme reflects the change in demand pattern. This will help customers save money by shifting their demand to less expensive times of day and reduce peak demand on grid. Flexible tariff scheme along with advance metering infrastructure (AMI), not only manages peak load, but also improves recovery ratio. DGwith solar radiation forecasting intelligence can prepare utility beforehand for switching over between DG and grid-feed, thereby reducing their deviation costs and the need for real-time balancing of feeder.

Financial viability and environmental sustainability of solarizing high loss areas will largely depend on a remuneration scheme that allows trading of the energy procured. A prevailing tariff structure in both third party and community distributed solar is feed-in-tariff (FiT), which is usually lower than the retail tariff. The consumer or the third party is paid for the accumulated sum of the solar energy units they generate and exports to the grid. However, instead of adjusting the units against his consumption, the consumer continues to get the supply from the utility grid at the retail supply tariff set by the utility. It is a policy mechanism that ensures the right of energy producer in the form of long-term agreement of power purchase at guaranteed prices. In case of centralized grid expansion and mitigation of high loss in feeders, there lies a possibility that distributed generations become stranded assets. Feed-in-tariff provides the developers an assurance of continued operation in parallel with grid at a determined tariff, with or without the transferring of assets to the utility, while working as a distribution franchisee.

### 4.1.3. Reduced US Dollar Indexation for Tariffs

The existing tariff regime relies heavily on promising returns in US Dollar to the project developer. This is linked to the project development and project finance where the funds for the projects are deployed in US Dollars linking them to the expectation of the project owners to get returns in the same denomination. While the tariff structures also include components of insurance and O&M, it is important to note that the US Dollar indexation leads to increased costs in Pakistani Rupees especially in the event of local currency devaluation.

Although this structure helps protect the investor from getting exposed to poor returns with currency devaluation, it exposes the customer to the same risk and ends up resulting in higher costs for the consumer of the energy value chain. As witnessed recently, prices of the electricity went drastically up due to rising prices of oil and gas, coupled with local currency devaluation. This has led to very high cost of energy for the electricity consumers, which would then lead to higher losses for DISCOs as there is a direct correlation between the price of electricity and its theft. The reduced indexation would help minimize fluctuation of the price of electricity for the end customer. It might be worthwhile to explore the idea of indexing less than 50% of the tariff rates to the US Dollar. This will protect the end customer from price fluctuations resulting from currency devaluation.

### 4.1.4. Facilitative Commercial Arrangements

Complex bureaucratic and administrative requirements in general deter investing in a particular sector, despite the strong economics. To help improve the speed of implementation of such projects and reduce transaction cost of associated processes, utilities should be responsible for providing official guidelines and one-window facility for obtaining an authorization to investment and reducing any ambiguities. Standardized legal and commercial documents would help in making the process more efficient and less costly. The focus should be on:

- Information asymmetry for investors and project developers
- Clear and enforceable long term PPA between the DISCO and the developer
- Speed up the process for the development and implementation of such projects

As part of the standardizing contracts for such projects, the regulator should also initiate price discovery through two stages:

- Pilot: Identifying a small number of feeders from each of the DISCO and developing pricing mechanisms for the project. This would help all stakeholders become aware of costs related to the projects and for the DISCOs to become familiar with the process. This would also be particularly helpful for the financiers to become familiar with the nature of the projects and develop financial instruments that can then deployed at scale.
- Scale: On the completion of the pilot, to streamline the process the regulator can propose upfront tariffs based on the lessons learned from the pilot. These upfront tariffs, along with standardized contracts, would very much speed up the process of initiating and deploying of projects across the country

### 4.1.5. Continuation of SBP's Renewable Financing Scheme

The State Bank of Pakistan introduced a refinancing scheme for Renewable Energy projects in the country in 2016. The scheme has played a critical role in the deployment of renewable energy projects by providing a reduced rate of financing for projects at the rate of 6%.

The scheme focuses on three different categories of projects that aim to provide solar PV energy to customers and the grid. For the success of renewable energy projects related to DISCOs, it will be critical for the policy to be continued to provide affordable financing for such projects. This would not only help improve the ease to access financing but also help to reduce the levelised cost energy for the projects resulting in lower tariffs for the projects.

To conclude, Pakistan's energy system is at a critical transition point. With thoughtful planning and strategic policy action plans, the country could not only displace fossil fuels and meet renewable energy as well as SDG 7 and SDG 13 commitments but also address the longstanding challenge of excessive losses in the energy sector. Solarizing high-loss feeders could prove a cost-effective, efficient, and easy-to-implement energy intervention with win-win solutions for all stakeholders. This, however, needs to be prioritized by the relevant policy makers. Against the context, a viable and fit-for-purpose implementation model to achieve quick and scalable uptake of cited PV growth in strategic areas would require interventions that could enable communities and corporate sector's role in this solarization drive.

# Annexure I

High Loss Feeders Questionnaire

**Sociodemographic**

1. I have the following (highest) level of education

    1. Illiterate
    2. Not formal qualification
    3. Primary education
    4. Secondary/Higher secondary education
    5. Undergraduate degree
    6. Postgraduate degree
    7. Other (Please specify) _________________

2. I am

    1. Student
    2. Employed
    3. Self-employed
    4. Unemployed
    5. Retired

3. My household income falls in the following bracket or What is your monthly household income?

    1. Less than 10000
    2. 10,000-20,000
    3. 21,000-40,000
    4. 41,000-60,000
    5. 61,000-80,000
    6. 81,000 or above

4. I describe my current income as

    1. Finding it very difficult to live on current income
    2. Finding it difficult to live on current income
    3. Coping on current income
    4. Living comfortably on current income

5. How much is the total expenditure of your Household Rs. per month?

___________________________________________________________

B- Background Information

6. Is this accommodation (where you live) your own or rented??

1. Own
2. Rented
3. Other

7. What is the dwelling type?

1. Independent House
2. Apartment/Flat
3. Part of the large unit (Portion)
4. Other

8. What is main fuel used for lighting?

1. Electricity
2. Solar Energy
3. Other (Please Specify

9. What is your average monthly electricity utility bill (in PKR)?

1. Less than 1000
2. 1000-3000
3. 4000-6000
4. 7000-9000
5. 10000-12000
6. Other: ________________________________________________________

10. Do you consider the monthly electric utility bill affordable?

1. Very much
2. Much
3. Somewhat
4. Slightly
5. Not at all

11. Does your locality experience load-shedding hours?

1. Yes
2. No

12. How many hours of load shedding do you experience?_______________________________________________

13. Please indicate to what extent does load shedding affect you

1. Very much
2. Much
3. Somewhat
4. Slightly
5. Not at all

14. Apart from grid-provided/conventional energy, are you relying on any other alternate/back up energy system for meeting your energy needs?

1. Yes
2. No
3. Other: ____________________________________________________________

15. Please indicate the type of alternate/back-up energy system?

1. Solar System
2. Generator
3. UPS
4. Other: ____________________________________________________________

16. What is the maintenance cost of alternate/back up energy system?

17. If this is a solar system, kindly provide the following details

1. System size kW_____________
2. Is the system is attached with battery______________
3. Is the system connected to grid (via net-metering) ______________

**C. Willingness to Install Solar system**

18. Have you ever seriously considered installation of Solar system? (if you already have the system installed, skip this question)

1. Yes
2. No
3. Other: ____________________________________________________________

19. If yes, Rate the following factors according to how important they are in discouraging you to install solar technology, where 1 means the factor is not important at all and 5 means the factor is very important. (Kindly ignore this question if you already have a solar system installed).

| | Not Important | Slightly Important | Moderately Important | Important | Very Important |
|---|---|---|---|---|---|
| High installation cost of solar technology | 1 | 2 | 3 | 4 | 5 |
| Lack of necessary knowledge/information | 1 | 2 | 3 | 4 | 5 |
| Lack of trust on technology | 1 | 2 | 3 | 4 | 5 |
| Lack of finance/borrowing opportunities | 1 | 2 | 3 | 4 | 5 |
| Lack of supportive policies | 1 | 2 | 3 | 4 | 5 |
| Lacking/Inadequate installation space | 1 | 2 | 3 | 4 | 5 |
| ong payback period/investment risks | 1 | 2 | 3 | 4 | 5 |
| Limited access to capital/solar technology | 1 | 2 | 3 | 4 | 5 |
| Other (Cite according to importance) | 1 | 2 | 3 | 4 | 5 |

20. How willing would you be to invest in solar technology if government provides the technology at subsidized rate?

1. Not at all willing
2. Not really willing
3. Undecided
4. Somewhat willing
5. Totally willing

(b)- If answered not at all willing or not really willing, why is this?

______________________________________________________________________________

21. How much you can pay for the solar system Rs. ___________________

# Annexure II

**Consultative Session Questionnaire**

1. How to optimally push sited solar PV uptake in high loss configurations?
2. What is the best alternative to host-owned installations in Pakistani context?
3. What enabling regulations/facilitative environment would be needed for implementing these models?

| Consultant No. | Viability of approach | Ways to adopt solar in high loss configurations | Suitable business model | Policies & regulation | Other comments |
|---|---|---|---|---|---|
| 1 | ✓ | With the promotion of net-metering and captive solar<br><br>Microgrids for off-grid areas rather than grid expansion<br><br>Digitalization of every power sector segment | Most suitable is CTBCM with maximum involvement of third party<br><br>Unbundling of market should decide the course of action and should have limited government involvement | Regulations of CTBCM support the third-party investments<br><br>Governance Issues in the DISCOs needs to be resolved | Needs system enhancement aspect i.e. installation of Automated metering infrastructure (AMI)<br><br>Better performance and consumer service of DISCOs |
| 2 | ✓ | Promotion of solar PV among consumers<br><br>Revising the current tariff framework<br>Increasing the penetration level of solar at distribution level | Global practices like net-metering, Feed-intariff and net-billing can be adopted<br><br>Micro-financing for solar installers to especially in case of CAPEX model<br><br>Utility-third party model can be opted provided if utility is independent<br><br>Third party PPA is more feasible | Inclusion of singlephase customers for net-metering and other bilateral energy transactions<br><br>Banks need to facilitate users in financing schemes<br><br>Third party financing regulations should be developPolicies should give assurances to investors | Financing institutes should evolve and support customers with energy use of 300-400 units<br><br>Professional development and training of DISCOs is required.<br><br>Solarising high loss feeders can ensure cheap electricity to customers |

| | | | | | |
|---|---|---|---|---|---|
| 3 | ✓ | Identify the losses based on rural-urban localities, technical -commercial losses, theft, and feeder-wise<br><br>Facilitate banks in financing mechanism | Business model based on third party PPA with utility is a feasible model<br><br>Feed-in-tariff is a successful structure<br><br>In load with high line losses, community solar is a feasible option | Regulations for investment/attraction of investors<br><br>Proper regulations for solar technology import are required | Utilities should play a passive role<br><br>For community dwellings like apartment system in Karachi, a third party PPA is more suitable |
| 4 | ✓ | Initiative and quick action from the regulator is required for this transition<br><br>Pilot projects of such model should be implemented and analysed for iterative improvement | Rural areas of QESCO, PESCO and TESCO have long lines and high line losses, community solar is a feasible option<br><br>PPA arrangements between investors and the local DISCO might pave the for such models | Regulation for possible pathways for these kinds of medium-scale plants needs to be designed<br><br>Regulator should arrange for such contracts and DISCOs need to assist investors by identifying suitable land | Shared a similar case study where DG insertion reduced the feeder line loss from 29% to 4%.<br><br>DISCOs benefit together with their consumers through better voltage levels during the day and less line losses |

| | | | | | |
|---|---|---|---|---|---|
| 5 | ✓ | Resolution of issues related to vertical integration of sector<br><br>Resolution of DISCO's administrative issues<br><br>Revising the regulations according to modern standards and needs Incentive based schemes can help in adoption of solar by consumers | A business model that supports customized tariff for loss areas<br><br>A model in which private investor sell energy as a merchant and sign a bilateral contract<br><br>Outsourcing of high loss feeders and contractual agreement with utility<br><br>Community solar model can be implemented on multi-story buildings | Regulatory frameworks that allow DISCOs to undertake projects independently<br><br>Regulations that allow DISCOs to determine tariff<br><br>Current average basket tariff regime should change<br><br>Regulations that bound the regulator to engage the DISCOs in planning<br><br>Regulations that separate the power sector into supply business and wired business | Northern and southern DISCOs have high losses<br><br>Under CTBCM, DISCOs issue generation license with third party<br><br>A model for unaccounted energy units should be proposed<br><br>Outsourcing the revenue collection on 11 kV lines is another solution for reducing losses. |
| 6 | ✓ | Ensure win-win situation for both distribution companies and discos<br><br>Tax breaks and incentives should be offer to investors and installer | A business model in which investor is a third-party and utility acts as a regulator too, giving them generation license<br><br>Auction model, where DISCO can hold auction for a feeder and outsource the operation, while third party installs the system based on the technical parameters | Regulations that channel the cross subsidies towards the installers<br><br>The contractual agreement should be a time bound and the ownership is given at the end of contract when the subsidized amount is paid for<br><br>Regulations that gives subsidies to utilities to uptake solar PV rather than consumers in billing | Discos should engage with regulator on their own and present the projects for DG insertion in high loss area of their jurisdiction |