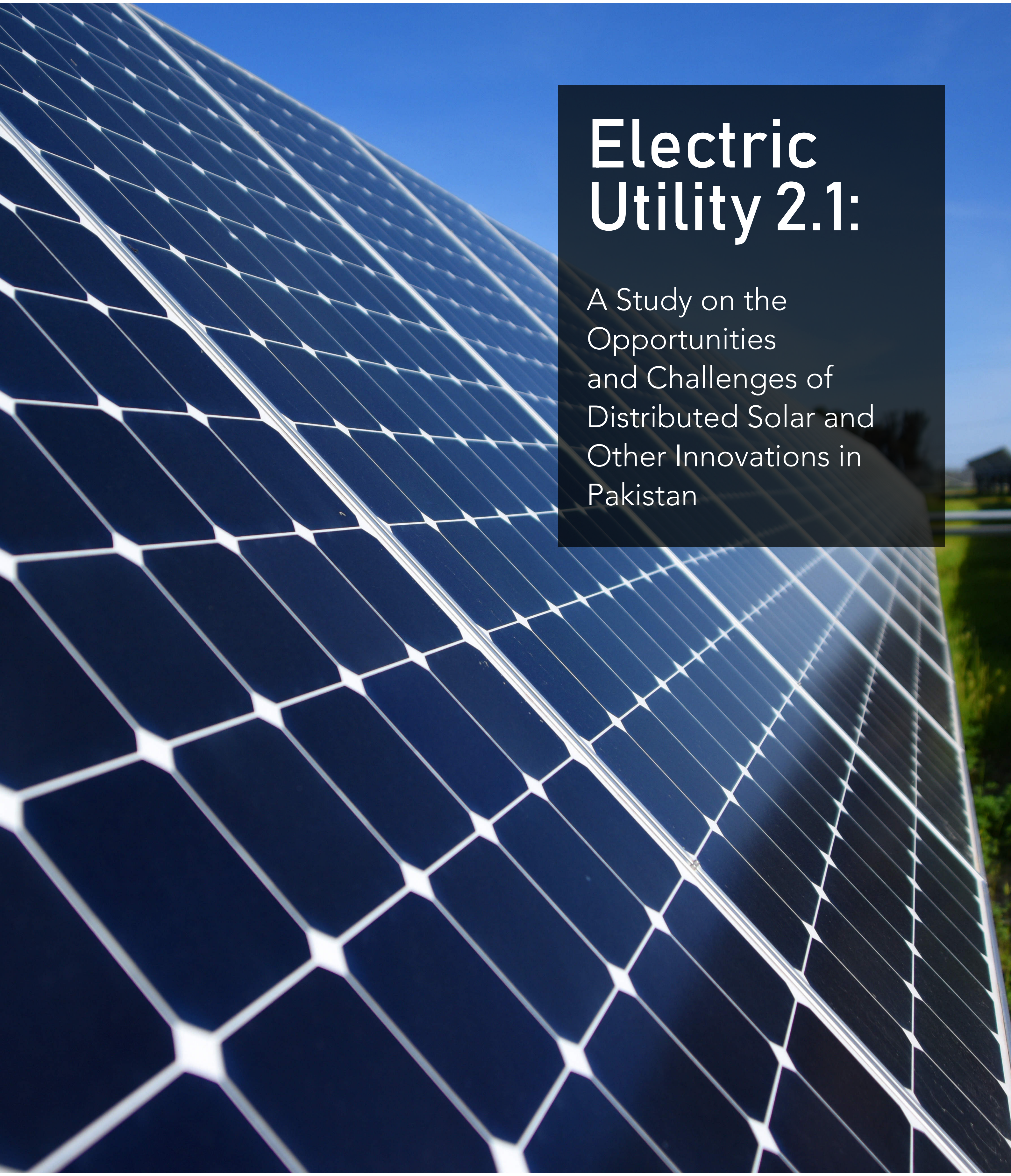
NAM Associates

Electric Utility 2.1:

A Study on the Opportunities and Challenges of Distributed Solar and Other Innovations in Pakistan



LUMS Energy Institute

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May 2019
Ramadan 1440

This report has been prepared by LUMS Energy Institute in collaboration with Hadron Solar, NAM Associates and Ignite Pakistan.

About LUMS Energy Institute:

This Energy Institute at LUMS is established to serve as a think tank, centre of technical excellence, knowledge network, and capacity building ground for the Pakistan to institutionalize a renewable rich future for Pakistan in the most sustainable and cost-effective way possible.

About Hadron Solar:

Hadron Solar is a solar solutions provider offering a range of end-to-end solar solutions for agriculture, commercial and residential sectors in Pakistan. Established in 2013, the company has delivered more than 200 projects with 1,650 kW+ installed capacity across Pakistan. With offices in Lahore, Karachi, Islamabad and Faisalabad, the company employs 40+ full-time professionals with vast local and international experience. Hadron Solar's management team includes widely recognized experts in solar energy, energy finance and public policy, with track records of building successful businesses.

About NAM Associates:

NAM Associates is a premier engineering construction firm in Pakistan. Established since 1983, NAM Associates offers construction management, design and execution of commercial, office and residential sectors nationwide. It has successfully delivered over 500 projects across multi-disciplinary sectors and has to credits esteemed clients including Standard Chartered Bank, Dubai Islamic Bank, Lever Brothers Pakistan Ltd, DG Khan Cement Company and Chand Bagh School besides many other esteemed groups.

About Ignite:

Ignite funds startups and innovative projects that utilize 4th industrial wave tech to solve local problems and target global opportunities in health, education, energy, agriculture, telecom, finance and other verticals. Our national network of incubators across Pakistan nurtures startups and engages them with investors and corporations.

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Preface

According to some estimates, solar, wind and other forms of renewable energy will generate over 85% of electricity by 2050. This transition towards renewable energy is coming faster than our imagination. Traditionally, electricity has been generated by utility scale electricity generators and the electricity business has been a monopoly due to full control of utility companies on the wire business. The uptake of distributed solar energy has changed this monopoly and now customers can produce their own energy with an option to export it back to the grid. Falling solar prices have made it attractive for customers to partially generate their own electricity and with falling battery prices, the customer may defect the grid altogether.

This onslaught of distributed solar has impacted the revenues of utility companies and many utility companies across Europe, USA and Australia have reported up to 80% drop in revenues during recent years. This disruptive change is forcing the utility companies to change their business model from a monopolistic regime to a more innovation oriented organization. Chances are that the utilities that do not take on challenge of distributed solar will slowly be trapped into the spiral of economic death. However, the models of a successful utility in this new age of distributed generation are few and far.

In Pakistan, the utility business is mostly regulated. However, our utilities are already facing the spiral of death due to rising electricity prices. Industries have been defecting the utilities in favour of captive generation and our industrial base load is down from 32% to less than 20% already. With distributed solar the good residential customer and small business customers may also start to leave the grid which will raise the price of electricity thus forcing more customers to resort to alternate energy solutions.

The goal of this report is to look at how the utilities around the globe are dealing with the phenomenon of distributed solar. After carrying out a thorough literature survey we have met with several professionals of the power sector in Pakistan on their views on this changing landscape of utilities. Finally, we looked at the current legislations, regulations and policies in Pakistan to suggest a utility model that is ready to take on the new challenges of disruptive innovations in the power sector. We are terming it Electric Utility 2.1 because on top of distributed solar and net-metering, it also considers their implication as well as other innovations the utilities can make use of along with them.

Finally, this report is made possible through funding by Hadron Solar and NAM Associates and Ignite National Technology Fund. Mr. Waqas Moosa, CEO of Hadron Solar, and Mr. Muhammad Akbar, CEO of NAM Associates, are among very few individuals in Pakistan's power sector who have contributed funds towards research and development at universities. Ignite National Technology Fund is the backbone of cutting edge research in Pakistan. Since universities are not profit making institutions, funding for research only comes through such public and private organizations. We hope that more public and private organizations will contribute towards research and development at universities which will enable evidence based policy and decision making.

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1 EXECUTIVE SUMMARY

All over the world, the trend towards clean renewable energy generation is gathering pace. States and countries across all continents have announced aggressive renewable and solar generation targets for the next few years. Within renewable energy, solar photovoltaics is a technology that has grown in importance over the past decade. The main reason for this is an 86% decrease in the levelized cost of solar generation from 2009 to 2017, making it cheaper than coal generation [1]. A total of $161 bn investment was made in solar energy in 2017 with 98.9GW installed. In 2018, 109GW were installed according to BNEF [2]. In addition to large-scale solar farms, distributed/rooftop solar generation has emerged as a hot trend on a global scale, which is the subject of this study. Rooftop solar brings with it certain indisputable advantages like clean energy supply to the grid, but it also comes with certain strings attached which must be managed. In particular, it turns the traditional utility operation on its head, cutting down on their revenues. This is problematic because the utilities, which are the backbone of the power sector, cannot be allowed to weaken. On the other hand, distributed solar is also essential, especially at a time when Pakistan is facing severe environmental issues, and looks set to be here to stay due to favourable economics even in the face of unfavourable policies. Consequently, a way forward that involves the utilities as well as accommodates distributed solar must be incorporated. Pakistan is a new entrant in the arena of rooftop solar and is presented with a clean slate at this point. It is imperative for Pakistan to learn from countries where this technology is finally reaching maturity after years of experimentation and policy changes.

The Decade of Innovative Disruptions

The past decade has seen numerous developments in the power sector, the kinds of which were not there previously. As a result, the power sector all over the world is undergoing massive changes. These developments can also be termed innovative disruptions, disrupting the traditional utilities' model and forcing them to come out of their comfort zones. Most utility companies across the globe are pondering over their future and how to best safeguard their business. The main innovative disruptions in the power sector can be described as follows:

- Solar and renewable energy sources: With decreased costs and increasing drive towards clean energy, renewable energy sources, especially solar and wind, are increasing their share rapidly across the world as mentioned above. The cumulative installed capacity of solar PV has risen exponentially since 2006, from 5GW to around 500GW today, with 98.9 GW installed in 2017 [3] and around 109 GW installed in 2018 [2].
- Distributed generation: Alongside utility-scale solar, rooftop solar is gaining popularity across the globe, cutting down on utilities' revenues. Some countries like Australia and Germany now have more distributed solar as opposed to utility-scale solar. In regions like Hawaii and Australia, 20% of all homes have now had solar installed [4][5]. In Pakistan as well, 950 MW worth of solar panels were imported in 2017, more than the past four years combined [6]. Although rooftop solar has its advantages, it has certain challenges that must be resolved upfront. Nevertheless, rooftop solar looks set to be here to stay and a pragmatic policy to guide it must be determined from the outset.
- Net-metering/Solar compensation: The availability of net-metering and compensation for rooftop solar fed into the grid has further complicated the utility business. The rate of compensation becomes a bone of contention between solar customers, utilities and non-solar customers. Net-metering has been a little slow to take off in Pakistan since its inclusion in legislation in 2015 with installations worth around 23 MW till now. Recently, there has been a surge in the adoption of net-metering due to the push by the government and easing of the net-metering process. The installed capacity

in the first three months of 2019 is already around half of that in 2018 (around 11 MW).

- Storage: Termed by many as the missing link in the transition to renewable energy, storage is another major disruptor in the traditional utility model. On one hand, it can supplement utilities by providing backup power and grid support services, while on the other hand, it can cause them loss of revenue when employed by rooftop solar customers. The cost of storage is going down rapidly with current prices down to around $200/kWh from around $1000/kWh in the late 2000's. As costs decrease further it will allow people to become more self-sufficient and disconnect more from the grid.
- Grid defection and the 'utility death spiral': As rooftop solar is gathering pace, the concept of grid defection is taking shape. Grid defection occurs when customers cut their grid usage, either partially or fully, by investing in self-generation, storage and generators. Although full grid defection is economically not feasible at the moment, partial grid defection is on the rise. The problem gets exacerbated because when people defect from the grid, electricity rates increase for the remaining customers to cover for fixed costs, which encourages them to defect as well. This results in a 'death spiral' for utilities that is a threat to their business.
- Smart grids: The concept of smart grids is also taking shape in a lot of countries. With increasing development of artificial intelligence and communication techniques, the grid can be made more intelligent by gathering data at various nodes and using the data to obtain useful information. A smart grid would be able to detect outages and faults beforehand, indicate equipment wear and tear as well as assist in energy efficiency programs. It would also provide a better visibility into distributed generation that would assist in matching supply with demand.
- Demand-side management: Demand-side management is a method by which demand is modified to meet shortages and excesses in supply. Traditionally, supply is made to follow demand but with better communication between utilities and customers, and increasing automation of electrical appliances, electricity usage can be altered according to supply at a particular time of the day. It works especially well with solar when certain appliances or industrial processes can be made to run at times of peak solar generation. Customers who cooperate with utilities in these programs can be compensated by the utilities in one way or another.
- Time-of-use pricing: Time-of-use pricing is a mechanism by which rates of electricity usage (and feed-in to the grid) are varied during the day, depending upon the supply and demand at that time. This can be used to implement demand-side management and works well with distributed solar. Rates of consumption as well as feed-in to the grid can be lowered during the day when solar is produced in excess, encouraging consumption and discouraging energy export to the grid. At night time, when solar generation is unavailable, rates of consumption and feed-in can be increased to reduce consumption and encourage export from distributed solar customers.
- Electric vehicles (EVs): EVs are picking up pace across the world with many countries announcing policies for incorporating EVs into their mix of vehicles. For instance, Norway plans to ban sale of fossil fuel based vehicles by 2025 [7], whereas India has announced to increase its share of EVs to 30% by 2030 [8]. EVs, with their battery packs and inverters, provide a significant amount of shift able load and potential grid services to the grid. They can be charged during times of excess supply and can possibly discharge to supply electricity to the grid in times of shortage. Again, this works effectively with solar generation and can be used to implement demand-side management.
- Electricity markets: Across the globe, with the privatisation and unbundling of the electricity sector, more flexible markets are taking shape. Power and energy are being traded in real-time markets on the wholesale end and the retail sector is also being opened to several participants. This would allow customers to select from several retailers which would create competition amongst them. In the future, the retailers can invest in all these innovations in varying degrees to attract customers, providing them customized packages along the way.

- Carbon trading: In more developed countries carbon trading is used as a tool to keep emissions in check. All relevant companies are assigned permits for a certain amount of emissions. If some company manages to reduce its emissions, it can trade its permit with another that went overboard. This provides a financial incentive for companies to cut down on their emissions and adopt renewable energy sources.

The main focus of this report is distributed solar as that is the main disruptor to the power sector with which other developments can be integrated. We discuss the benefits and challenges associated with distributed solar in order to propose recommendations for the path utilities can take in the future.

Distributed Generation Benefits

Distributed solar has a number of benefits which can be summarized as follows:

- Clean Energy: Distributed solar provides clean energy by utilizing the energy from the sun. In a country like Pakistan, with critical amounts of concentration of pollutants in the air, this is something that is desperately needed. Every year, major urban centres experience smog, which is detrimental to eyes and lungs of their citizens. Lahore and Faisalabad have been listed amongst the top 10 most polluted cities in the world [9]. The energy sector, along with transportation, makes up the biggest source of pollutants in the air. If the transportation sector can be electrified and the energy sector shifted to renewables, a major part of the pollution problem in Pakistan can be solved.
- Supports grid supply: Distributed solar adds quality power to the grid, helping it meet demand with supply. It helps the utilities avoid the expensive power they need to purchase in order to meet the last few megawatts required to meet the demand. This is because the generation sources are committed based upon their costs and in order to meet more demand, more expensive units need to be purchased. Furthermore, with distributed solar, due to much lower investments, the unfavourable contractual terms generally offered to large-scale power plants can be avoided. Last but not least, distributed solar can be used in tandem with local generation in isolated grids to provide indigenous power to locals.
- No need of additional infrastructure: Added to the fact that distributed generation supports the utilities in matching supply with demand, it doesn't require any additional infrastructure. No additional lines or poles need to be built by the utilities.
- Significantly less losses: By supplying energy so close to demand, distributed solar also prevents most of the losses associated with the conventional supply of electricity. Losses are a big problem in Pakistan, with figures around 19.8% of the total electricity supplied [10].
- Better maintenance: As opposed to utility-scale solar, distributed solar encourages better maintenance and more production. This is because with distributed solar the installer has the incentive to produce more energy to consume or feed in to the grid, as opposed to utility-scale solar where investors are paid for full even if less amount of energy is produced.
- Grid stability using inverters: Distributed solar involves the use of inverters that have functionalities that can be used to stabilize the grid. Inverters can provide ancillary services to the grid by absorbing or injecting reactive power to the grid to cover up for short term fluctuations. They can also shape the wave up to the 8th harmonic to assist the grid as needed.

Distributed Generation Challenges

Despite its numerous benefits, distributed solar also has its challenges. However, these challenges are far from being unsolvable and can be solved by planning for them in advance. The main challenges of distributed solar are as follows:

- Revenue erosion for utilities: The biggest hurdle in the way of rooftop solar is the fact that it cuts down the revenues for utilities, making enemies out of them. Furthermore, with net-metering, utilities have to purchase electricity at retail rates, again nullifying their profits. Add storage to the mix, and the case for full grid defection starts to take shape. Furthermore, these defections are mainly from the good customers with high electricity demand like shopping malls, industries and universities. Pressure is being felt by utilities and in many regions, like Nevada, there have been accusations of utilities' lobbying to push for policies that discourage solar. In Hawaii utilities suffered a 21% loss in sales from 2007 to 2016 [11]. Utilities in the US are expected to lose $18 to $48 billion per annum over the next decade [12].

- Rate mechanism and unfair distribution of fixed costs: Another challenge with rooftop solar is to get the compensation right for feeding in electricity to the grid. The utilities are of the view that because solar customers consume less electricity, they do not pay their fair share of fixed costs because billing is only done on units consumed. The fixed costs are spread amongst non-solar customers, which get to subsidize solar customers. On the other hand, distributed solar provides several benefits to the grid and cannot be simply valued at the wholesale rate. Fixed and demand charges are increasingly being proposed by some utilities to balance this problem.
- Grid instability: A genuine challenge associated with rooftop solar relates to its integration with the grid. As more and more rooftop solar gets added at a local substation transformer, the local grid starts to get unstable. This is because the energy produced by these units cannot go beyond the transformer which has been currently designed for one-way flow for radially fed systems. Backfeed, rising of voltages, fault current limitations, transformer wear and tear and voltage flicker are some of the issues that can occur with excessive rooftop solar [13][14][15]. All these issues need to be addressed and installations must be planned and standardized.
- Demand-supply matching: With more and more rooftop solar installations it would get increasingly difficult for utilities to perform demand- supply matching unless it has data of the installations as well as visibility or information on their production.
- The 'Duck Curve' problem: This problem is a result of solar on the grid in general, distributed or utility-scale, but would nevertheless be manifested as more and more rooftop solar is added. Because conventional generation needs to ramp up in the evening to cover up for fading solar, a minimum amount of it needs to be operated even when solar is at its peak. Apart from this, a certain amount of conventional generation is also needed for backup and provision of ancillary services during the day. This minimum generation sets a limit to the amount of solar that the grid can have, beyond which it would need to be curtailed. California and Germany have had to sell electricity at negative prices due to this problem. Introducing fast-ramping plants as well as storage to the mix can alleviate this problem along with demand-side management and introduction of electric vehicles.

The Critical Need for Planning for the Future

It is imperative to mention that rooftop solar looks set to be here to stay and cannot be left unattended. Even in the presence of a harsh policy or an absence of one, it should proliferate simply due to economics. If it grows on its own, it will create huge problems for the government as it has done for various countries across the world. At that time a knee-jerk reaction would not work. Rooftop solar has already started to bloom in Pakistan with more and more homes, industries and shopping malls shifting to solar in the face of rising electricity rates. In 2017, 950MW worth of solar panels were imported, more than the past four years combined. The installed net-metering capacity for the first three months of 2019 is already around half of that in 2018 (around 11 MW). Furthermore, battery costs are rapidly decreasing and might soon become economically feasible for customers to further defect from the grid.

Along with the increasing trend of rooftop solar, Pakistan already has excess generation planned for the next few years without keeping in mind distributed generation. It has signed up for 62000MW of generation, whereas the demand is only expected to reach 40000MW by 2022. Furthermore, 5000MW of rooftop solar can be expected to be online by 2022 [6]. The greater the excess generation, the higher the demand charges the government needs to pay. Even without taking into account distributed solar, the capacity payments are expected to reach 1500 billion Rs by 2025. Hence a comprehensive power plan for the future, taking into account distributed solar, must be developed.

Suggested Future Course of Action

An interesting development coming up in Pakistan which can be made use of in devising a strategy for distributed solar is the restructuring of the electricity distribution sector in Pakistan. According to the NEPRA Act 2018, by 2021, distribution companies are going to be divided up into retailer companies and companies handling the wires and infrastructure business. This development combined with the need to accommodate rooftop solar into the utility model, allows for new business models to be investigated.

In light of the benefits and challenges of distributed solar, as well as the upcoming legislation in the power sector, we have proposed the following recommendations for the power sector, keeping in mind the experiences of other regions with distributed solar. These have been discussed in detail in the section on the future utility model in this report.

In order to overcome the basic revenue erosion problem, the utilities must look into one or a combination of following three approaches;

- Utilities should invest into ownership of distributed solar. This has already been proposed by Arizona Public Service in the past and is increasingly being pushed by many analysts. Utility ownership can be approached in two ways. For one, utilities can build and own complete systems on homeowners' rooftops and adjust the costs in the electricity rates. Alternatively, utilities may partner with third parties who would also build and maintain the installations, purchasing electricity from them and selling to customers at a profit. In exchange for ownership, utilities can compensate the owners of premises by paying them a monthly rent or offering them a reduced electricity rate.
- Alternatively, a "buy-all-sell-all" policy for distributed solar can be introduced in which the solar customer either sells all of the produced energy to the grid at a rate higher than wholesale but less than retail rate or entirely self-consumes. This would ensure that as long as the customer is engaged with the grid, whatever energy is produced goes through the hands of utilities, avoiding the utility revenue erosion problem.
- In the face of consumers becoming "prosumers", the abilling mechanism must be revamped. Going forward, utilities must separate revenues from units of energy as their ultimate goal is revenue not production. There are three main things they can do:
  1. Solar customers can be charged certain fixed charges because, although they are consuming less units, they are still using the grid for buying and selling energy.
  2. Instead of net-metering, a less than retail rate feed-in tariff should be introduced to allow utilities to make profit out of the purchased electricity. Net-metering, due to decreased costs of solar, has now become an obsolete program, intended for initial solar uptake which is not needed now.
  3. Demand charges, based on maximum load, can be introduced to even out costs between solar and non-solar customers because the capacity has to be built for the maximum load even if the customer consumes less overall units.

Additionally, the utilities must look into the following points to maximize the benefits of rooftop solar and upcoming innovations in the energy sector.

- Feasibility studies should be conducted at selected typical feeders to get an idea of the amount of solar that can be added to local feeders across Pakistan. Detailed studies should be conducted on specific feeders where rooftop solar nears the maximum limit.
- In order to effectively utilize solar, time-of-use pricing should be employed so that people consume more electricity during the day when production is high and less when the sun is away. The same can be done with feeding electricity to the grid. Feeding in would be compensated less during the day and more at night when energy is more needed by the grid. This would also encourage the use of storage among customers which would help in the integration of renewables in the system.
- In the long run utilities must invest in storage. This would help them immensely in the following ways:
  1. It can provide backup power, in which case it would be like another supply source in the CTBCM. This would also provide a buffer against the 'Duck Curve'

problem.

2. It can provide instantaneous grid stability in response to fluctuations in power (ancillary services). In advanced electricity markets these are traded as very expensive sources of electricity.
3. It can be situated at a smaller scale at transformer level in areas where excess solar is expected. This would also prevent customers from investing in storage themselves that can be detrimental to the utilities.

- Utilities should invest in data analytics. Although it would take some effort to set it up but in the long run it would be very beneficial. It would allow them to better manage equipment, better match supply with demand, cut electricity theft and provide energy efficiency programs to customers. Solar installations would be helpful in this because they already include inverters and possibly other monitoring devices that could be used for this purpose.
- Utilities must reinvent themselves and engage more with the individual customer like telecomm companies do. With the new legislation, the retailer side of utilities would only be concerned with purchasing power and selling it to customers. They can utilize all the new developments mentioned in this report like demand-side management, time-of-use pricing, energy efficiency programs and EVs to come up with customized packages for owners based on their situations.
- The government must also step in to incentivise clean energy and rooftop solar to alleviate the ailing environmental conditions. This can be done by giving tax credits to solar customers, setting renewable energy procurement targets for utilities and implementing carbon trading. Pilot or demonstration projects can also be arranged. to increase acceptability among masses.

2 INTRODUCTION

All over the world, the trend towards clean, renewable energy generation is gathering pace. States and countries across all continents have announced aggressive renewable and solar generation targets for the next few years. For instance, California has set a renewable portfolio target of 33% by 2020, 60% by 2030 and 100% by 2045, which does not include hydro. The 2020 target was already crossed in 2018 with 34% of generation from renewable energy sources [4]. India has set a renewable energy target of 175GW by 2022 [17].

Within renewable energy, Solar Photovoltaics is a technology that has grown in importance over the past decade. The main reason for this is an 86% decrease in the levelized cost of solar generation from 2009 to 2017, making it cheaper than coal generation [1]. It is for this reason that in some countries, in addition to renewable generation targets, targets for solar generation have also been set. For instance, China had set a target of 105 GW of solar which was already crossed in 2018 with 165GW of solar by the month of September [18]. India has a target of 100GW solar by 2022 [17]. Solar installations all over the world are on the rise with installations worth 53GW in China, 10.6GW in US and 9.6GW in India in 2017 alone. A total of $161 bn investment was made in solar energy in 2017 with 98.9GW installed. In 2018, 109GW were installed according to BNEF [2].

In addition to large-scale solar farms, distributed/ rooftop solar generation has emerged as a hot trend on a global scale, which is the subject of this study. Reduced costs of solar and storage, combined with environmental concerns and favourable government policies have been the main drivers for this surge. This trend has been more pronounced in some regions more than others. In Australia, by December 2018, 2 million households (20% of all households) had solar systems installed with total capacity reaching 7.9GW [5]. In Hawaii, due to exorbitant electricity rates, around 20% of all households have solar installation. In 2017, 70% of all solar capacity installed in Hawaii was rooftop solar [4]. In California, the top state in the US with respect to solar energy, has mandated solar installations on all new homes starting 2020 [19].

In Pakistan, rooftop solar is picking up pace with 950MW worth of panels imported in 2017, more than the numbers combined for the four previous years [6]. Net-metering, legislated initially in 2015, is also gathering pace with around 50% of installations for 2018 (11 MW) already covered in the first three months of 2019. With the prices of solar and storage further plummeting and awareness on the rise, the numbers are only expected to grow. The purpose of this report is to chart a path forward for the government of Pakistan in light of other countries' experiences in welcoming rooftop solar in an effective manner.

Although rooftop solar brings with it certain indisputable advantages like clean energy and load-balancing on the grid, it also comes with certain strings attached which must be managed. Rooftop solar is unique in that it turns the traditional utility operation on its head. This is also its biggest issue at the moment. Electricity has traditionally been supplied by the utilities to the customers in a uni-directional way. The utilities used to generate or purchase wholesale power and sell it to the customers. No matter who was the generator, the eventual revenue fell into the hands of the utilities, which were also tasked with the maintenance of the grid.

With distributed solar, the customer has begun to generate electricity. Irrespective of whether he sells excess energy to the utility or not, he is now buying less electricity from the utility, which results in lower revenues for the utilities. This naturally puts him into a collision course with the utilities. Additionally, if he puts electricity back into the grid, the rate at which this takes place is another cause for contention with the utility. Furthermore, as more and more solar gets fed into the grid, there is a chance of grid instability, which again the utilities have to manage.

Due to the above-mentioned points, distributed generation, with all its advantages, has become a disruptor for the utilities' business. The utilities themselves, which are the backbone of the power sector, cannot be allowed to weaken. Distributed solar must not be stopped, especially at a time when Pakistan is facing severe environmental issues, having been declared the seventh most vulnerable country to climate change [20]. Consequently, a way forward that involves the utilities as well as accommodates distributed solar must be incorporated. Luckily, all of these problems have been experienced by others in one way or the other. Pakistan is a new entrant in the arena of rooftop solar and is presented with a clean slate at this point. It is imperative for Pakistan to learn from countries where this technology is finally reaching maturity after years of experimentation and court cases.

An interesting development coming up in Pakistan which can be made use of in devising a strategy for distributed solar is the restructuring of the electricity distribution sector in Pakistan. According to the NEPRA Act 2018, by 2021, distribution companies are going to be divided up into retailer companies and companies handling the wires and infrastructure business. This development combined with the need to accommodate rooftop solar into the utility model, allows for new business models to be investigated. As the retailer would only be concerned with procuring power and supplying it to the customers, it can have a program for buying electricity from rooftop solar customers in a fair manner. The companies involved in the wires business can charge a fixed cost for connection to the grid or a cost proportional to the energy transaction.

It is imperative to mention that rooftop solar looks set to be here to stay and cannot be left unattended. Even in the presence of a harsh policy or an absence of one, it will proliferate simply due to economics. If it grows on its own, it will create huge problems for the government as it has done for various countries across the world. At that time a knee-jerk reaction would not work.

Furthermore, Pakistan already has excess generation planned for the next few years without keeping in mind distributed generation. It has signed up for 62000MW of generation whereas the demand is only expected to reach 40000 MW by 2022. 5000 MW of rooftop solar can be expected to be online by 2022 [6]. The greater the excess generation, the higher the demand charges the government needs to pay. Even in 2017, the government paid 350 billion Rs in capacity payments as the capacity is built for peak demand over the year. In 2018-19, Pakistan is expected to use 128 TWh out of the 169 TWh generation capability, with capacity payments amounting to 664 billion Rs of which 162 bn would be for idle capacity. Even without taking into account distributed solar, the capacity payments can reach 1500 billion Rs by 2025.

In light of the above-mentioned points, a comprehensive power plan taking into account distributed solar must be developed. Distributed solar, with its generation patterns also bodes well with other new trends coming in the power sector which can also address excess generation issues. These include adoption of electric vehicles (EVs), demand-side management and smart grids. A step in the right direction with these crucial technologies of the future can go a long way in solving the power issues that can confront Pakistan in the future.

3 THE DECADE OF INNOVATIVE DISRUPTIONS

The past decade has seen a myriad of innovations taking place in the energy sector. A few of them have been explained below.

3.1 Solar Photovoltaics and Other Renewables

Solar photovoltaics (PV) is a technology that involves converting solar energy from the sun into electrical energy. It normally consists of a solar panel and an inverter with the possible addition of storage along with a charge controller. It started to gain importance around the latter half of the 2000's with Germany taking the lead with its Energiewende program. Total installed solar capacity in Germany reached around 34 GW in 2012 [12], more than 30% of the total solar energy capacity in the world. Countries like US and Japan have been in the race with Germany from the start, with many more countries like China and India investing heavily in solar over the past few years. The cumulative installed capacity of solar PV has risen exponentially since 2006, from 5GW to around 500GW today, with 98.9 GW installed in 2017 [3] and around 109 GW installed in 2018 [2]. In 2017, China led the way with 53GW followed by US with 11.8GW and India with 9.6GW.

The rise of solar PV has mainly been due to improved economics because of better and more efficient technology and economies of scale. The cost of solar panels has decreased by 75% over the last decade. The figure below shows the levelized cost of energy for several generation technologies [1]. This price reflects the actual cost of generation considering all the peripheral costs. It can be observed that the cost of solar has significantly plummeted and is now lower than coal-based generation.

Apart from solar, other renewable energy sources, not the focus of this report, like wind, bagasse and biomass are on the rise due to falling costs and the drive towards clean energy. However, the main renewable energy sources, namely solar and wind, are still held back by their intermittent and unpredictable nature. Storage remains the missing link which could really strike the final blow for these technologies. According to IEA, by 2050 solar will reach a capacity of around 4700GW, becoming the biggest source of power globally [22]. It is to be noted that IEA has been consistently falling short of predicting the growth of solar PV in the past [23].

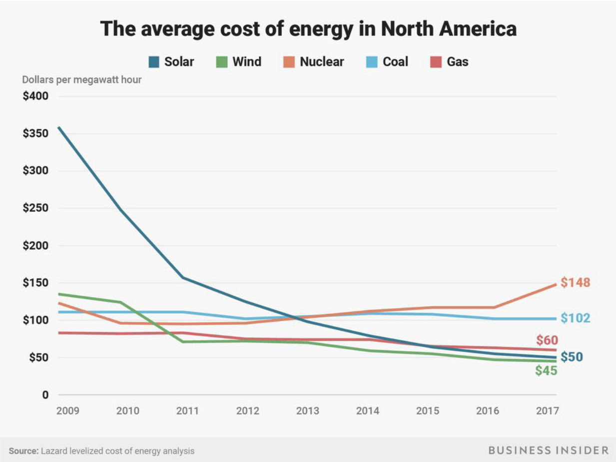

Figure 1: LCOE of different energy sources [1]

3.2 Distributed Generation

Distributed generation can be termed as the biggest disruptions to utilities since their inception. Distributed generation is when energy is produced at or close to the site of consumption, mainly for self-consumption. Distributed generation has existed before with some large industries having their own generation plants close to their sites but with solar PV this phenomenon has taken a new dimension. Solar panels are small in size, modular, portable, relocatable and cheap. Rooftop solar took off around the start of this decade and has been flourishing ever since. A major reason for this growth has been the subsidies provided by governments all over the world. Along with that, state renewable energy targets and the drive towards clean energy have contributed towards its uptake.

Distributed generation provides clean energy at the point of consumption and reduces stress on the grid. It can also have certain other advantages over large scale solar plants like China discovered in 2013 when it shifted its solar policy towards distributed solar [24]. Utility-scale contracts encourage installation but not actual production, resulting in poorer quality systems and lack of maintenance. This is because even if the solar installation does not provide optimum power, the owner is paid the full rate of original production. Furthermore, utility-scale farms are generally located far from demand centres resulting in higher losses and additional grid infrastructure costs. On the other hand, distributed solar requires little or no additional infrastructure while incurring less losses due to proximity with the demand. It also encourages maintenance on the part of the installer in order to maximize production.

Distributed solar has proliferated rapidly over the past few years with some countries like Australia and Germany having more of distributed solar as opposed to utility-scale solar. In both Australia and Hawaii, around 20% of homes have installed solar systems [5][4]. California has mandated all new households to have solar systems installed beginning 2020 [19]. In Pakistan, 950MW worth of solar panels were imported in 2017, more than the previous four years combined [6].

As with every new technology, distributed generation brings with it certain challenges that are solvable. An entire chapter is dedicated to this topic in this report.

3.3 Net-Metering/Solar Compensation

Distributed solar is complemented by compensations provided for selling excess electricity to the grid. Actually, these compensation mechanisms were what got rooftop solar out of its blocks. There are various ways of compensation with net-metering and feed-in-tariffs (FiT) being the main ones and other forms being variations of these. Net-metering simply measures the balance of electricity consumed against electricity supplied by the customer and either charges or credits the customer accordingly. With FiT, a separate meter is installed at the customer's site that measures the energy supplied by the customer and credits the customer at a rate different from the retail rate, usually greater, up until the past few years. Net-metering, in effect, can be thought of as FiT with a compensation rate equal to the retail rate while employing only a single meter. In many regions now, certain fixed connection charges or demand charges are also applied to solar customers, as volumetric rates are perceived to be unfair by utilities to non-solar customer. All over the world, regions where solar has proliferated are now experimenting with different rate mechanisms as the initial policies have served their time. In US alone in 2018, every state except for Alaska, Wyoming and Georgia took policy actions on distributed solar [25].

A mechanism for inducting electricity into the grid by the solar system is essential in the absence of storage. The reason for this is that due to the sun's pattern, solar systems generate more electricity during mid-day and stop producing when the sun is down. If there is no mechanism to store the excess electricity or put it in the grid, the excess electricity would get wasted. As a result, very little solar would be employed, just enough to meet the installer's peak load during mid-day.

As storage is still expensive, net-metering/FiT schemes have allowed customers to channel excess solar, resulting in installation of larger systems. These compensation schemes are decided by lawmakers and passed as part of legislations. Initially, compensation for solar was heavily tilted towards solar customers to kick start rooftop solar, with some regions even offering rates multiple times the retail rate. For instance, the rate initially in Canberra in Australia was 60 cents in 2009, 3.88 times the retail rate [26]. Over time, with the increased adoption of rooftop solar, falling solar costs and declining utilities revenues, the compensation has gradually lowered. In most regions now, the compensation rate has gone below the retail rate and rightfully so, according to several analysts. According to them net-metering was a program designed to kick start rooftop solar and had served its purpose. Nevada, in June 2017, following the roll-back of net-metering amid scores of protests, adopted an approach of reducing the compensation tariff in four tiers from 95% of retail rate to 75% as more and more rooftop solar capacity was added. The first tier of 80MW was completed in around a year in August 2018 [27]. Some researchers are also talking about a time- and/or location-based tariff, to rate solar exported to the grid according to its value to the grid at a particular time of the day at a particular location [28].

It is pertinent to clear a misconception here that although with net-metering, power is being injected into the grid, it cannot go past the local substation transformer as it has traditionally been designed work in one direction in radially fed systems. Excess solar, more than the demand under a particular transformer, can actually cause problems to the grid, as explained in another chapter. That is why a limit, usually around 15 to 30%, is set on the amount of solar that can be connected under a particular transformer. Once this limit is reached any new customer that wants to install solar would not be able to feed excess electricity into the grid. As a result, he would be limited by his minimum daytime load (to prevent oversupply), unless storage comes into play.

Net-metering in Pakistan was approved by NEPRA in 2015. Since then, around 1100 distribution licenses worth around 23 MW have been issued by NEPRA. LESCO and IESCO have been the frontrunners so far with around 8.5 MW and 6 MW respectively. Net-metering uptake has been slow so far but with increased initiative from the government and easing of the net-metering application process, it is finally picking up pace. The numbers for the first 3 months of 2019 have already covered around 50% of those for 2018 (11 MW).

3.4 Storage

Storage has long been touted as the missing link with renewable energy. The biggest issue with renewable energy, especially wind and solar, is its intermittency. If somehow energy could be feasibly stored during renewable energy generation and discharged in times of non-generation, the transition to renewable energy would be complete. Although storage technologies have existed, they have been expensive to be used at a large scale. The major forms of storage technologies are compressed air energy storage (CAES), pumped hydro storage and batteries. It is batteries that have recently made giant leaps into becoming a feasible storage solution, boasting several successful examples along the way.

Batteries differ from other storage forms in that they are portable, require relatively less space and are fast to respond, able to respond within 2 seconds. Furthermore, the cost of batteries has been decreasing quite rapidly. Battery costs decreased from around $1000/kWh in 2010 to $230/kWh in 2016. Furthermore, the cost of batteries has been beating predictions consistently. The predominant battery technology for electricity storage is the lithium-ion technology, with research underway on several other technologies like sodium-based technologies. With more and more research being performed in this area, the cost of storage is expected to further plummet, as can be seen in the graph below.

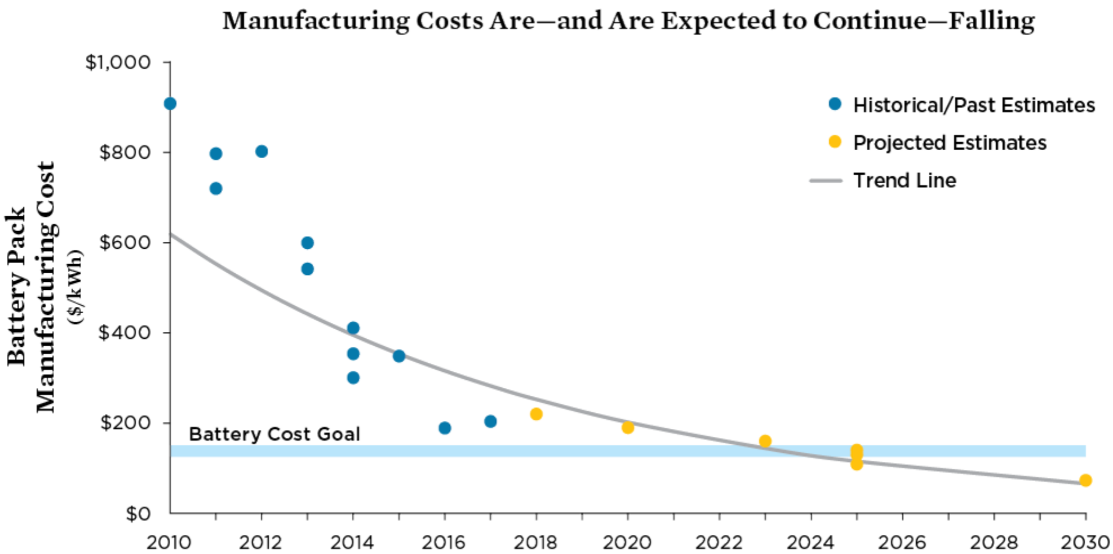

Figure 2: Falling costs of storage [29]

Besides providing backup, batteries are an effective source of providing grid-balancing, that is managing short spikes and dips in demand or supply. In South Australia in 2017, Tesla installed 100 MW/129 MWh worth batteries paired up with the 2 GW Hornsdale wind farm. It cost A$ 90.6 million to build and recovered more than 25% of its costs in the first 6 months. A majority of the revenue (A$ 13.1) actually came from providing network services while the rest (A$ 10.8) came from sale of stored energy [30].

Besides this, there are countless other examples involving electricity storage across the world, growing every year. For instance, SCE, a major utility in California, installed two 10 MW Tesla systems worth 80 MWh at a Mira Loma substation to replace natural gas peaker plants. This is enough energy to power 15,000 homes for four hours. The systems were successful, supplying energy every day. In Abu Dhabi, 15 systems of sodium sulfur batteries have been deployed across 10 locations, adding up to 108 MW and 648 MWh in total [31]. The project has been described as the "world's largest virtual battery plant". The individual systems can be controlled as a single unit as well as individually if local grid support is needed. The purpose of these systems is to balance the grid as mentioned above as well as provide 6 hours of electricity backup for outages.

The decrease in storage costs is alarming for utilities and must force them to act soon. As storage costs further decrease, people would be encouraged even more to install solar systems, as they would have to worry less about selling electricity to the grid. They would also not have to worry about the cap on solar connections to the grid as they would even be able to operate independent of it. Hence, solar-plus-storage can be termed the biggest danger to the utilities business. Utilities must reinvent themselves around both before it is too late, as can be figured from the sub section below.

3.5 Grid Defection and the 'Utility Death Spiral'

As a result of distributed generation and storage, a new phenomenon called grid defection has emerged, which has come to haunt utilities. This basically means customers defecting from the grid, either partially, by self-generating a part of their generation needs, or fully, by completely letting go of the grid. Partial grid defection is already in effect as rooftop solar is blooming. Full grid defection is still far because a large amount of still-expensive battery storage would be required to cover up for solar intermittency and successive cloudy days. Nevertheless, the Rocky Mountain Institute predicts favourable economics for full grid defection to start by early 2020's in major US regions including New York state, with Hawaii already past grid-parity [32].

Grid defection in any form is not good news for the utilities. Furthermore, as people defect from the grid, the fixed costs need to be covered by the remaining customers, hence raising electricity costs. This encourages the remaining customers to also defect from the grid. This phenomenon has been termed the 'utility death spiral', a vicious circle of consumer defections from the grid. The worst part for the utilities is that 'fighting' solar or 'flighting' away from solar would not work [33]. This is because the economics are moving so fast in favour of solar and storage that even anti-solar policies might not matter in a matter of a few years. The utilities must 'innovate', and must do it fast.

A lot of utilities over the world are feeling the heat from grid defection and are innovating. For instance, E.ON, one of the biggest utilities in Germany, experienced a 75% reduction in shares over eight years. Following this it split into two, with one company focusing solely on renewables. Some other utilities like AGL Energy in Australia partnered with a California-based storage provider, Sunverge, in 2016 to provide storage systems to 1000 existing solar customers [35]. Besides this, several utilities have invested into distributed generation with SDG&E in California investing in installation of solar systems for customers on the utility side of the meter [36]. Lastly, Commonwealth Edison in the US is trying its hand in a new business opportunity, selling data analytics and management services to their customers for better energy management, covered in the topic below [37].

3.6 Smart Grids

Smart grid is a relatively recent concept that has emerged in the energy sector. As its name implies, it involves making the entities involved in the energy generation, distribution and consumption more intelligent using Artificial Intelligence and Machine Learning to make the grid more efficient, secure and stable. It involves deploying devices at different consumption and distribution points that measure data which is

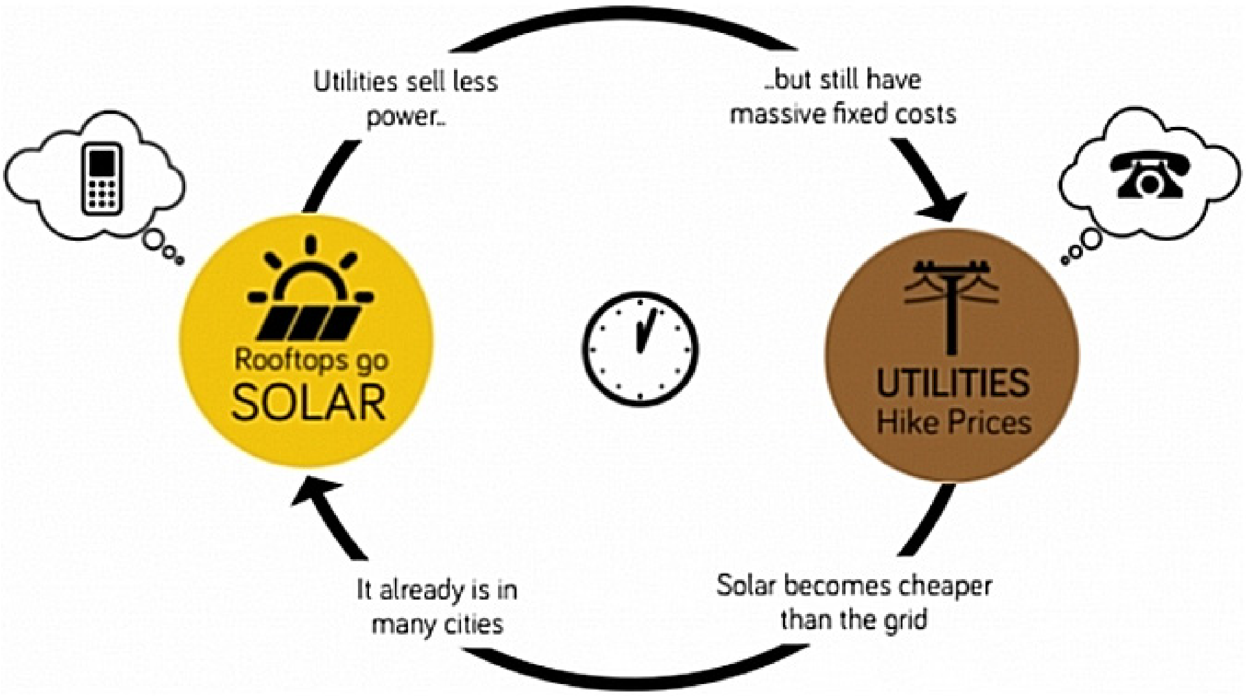

Figure 3: 'Utility death spiral' illustrated [34]

analysed to better manage and control the grid. For instance, demand patterns at a particular locality can be observed and supply can be apportioned to it accordingly. Besides this, data from different devices as well as knowledge of fault patterns can be used to indicate problems before they actually happen. Smart grids also provide an opportunity for utilities to perform data analytics and advise customers to better manage their electrical resources.

3.7 Demand-Side Management

Demand-side management (DSM) fits in well with the other disruptions mentioned above. DSM basically means managing the demand of the users to match supply and demand. The electrical grid is a system in which supply must match demand at all times, otherwise the system would be unstable. Traditionally, with no real-time communication between the utilities and the customers, supply has had to match the demand. However, today, with better communication between utilities and customers, as well as the drive towards smart grids, it is possible to have customers adjust their loads according to the status of the grid supply. For instance, high-consumption devices like washing machines can be run or programmed to be run during non-peak times of electricity demand. Similarly, electric vehicles can be charged during non-peak times.

There are several different ways to make DSM work. The simplest case would be for the utilities to call or message customers to lower their usage. Alternatively, with smart grids, utilities can have access to some of the customers loads which it can control according to supply. All of this would of course be with a contract with the customer, compensating him in the process. Several pilot projects have been conducted around the world with decent success so far.

It must be mentioned that smart grids and demand-side management work very well with solar. The main hindrance in the way of DSM is the fact that consumer behaviours change very slowly. However, if the customer has installed solar which produces excess electricity during a certain time and then fizzles away, he would have a greater incentive to shift his load. It would help him utilize solar much more effectively in the absence of storage. Along with solar, another thing that can help achieve DSM is having variable rates during the day based on the demand and supply situation, as described below.

3.8 Time-of-Use Pricing

Time-of-use (TOU) pricing is an interesting concept that bodes well with the concept of solar generation and demand-side management. This basically means charging different rates at different times of the day according to the supply of electricity. In times of electricity shortage, the rates can be increased and in times of glut they can be decreased. This can help with demand-supply management and grid stability, especially as more and more solar is added to grid. For this reason, in Hawaii, where there is too much rooftop solar, the electric company, HECO, plans to use time-of-use pricing to handle it [38]. A basic form of time-of-use pricing is already there in Pakistan with peak and off-peak electricity rates.

Time-of-use pricing complements solar energy perfectly. As storage is still expensive, there is generally a limit to the amount of solar that can be produced because it has to be consumed right away. With time-of-use pricing, customers can be encouraged to consume more electricity during times of peak solar production by reducing rates at these times. A lot of the loads in the industrial sector as well as the residential sector can be shifted around during the day. For example, automatic washing machines can be set to operate during peak solar hours when the rate of electricity is lower. Similarly, certain industrial processes can be run at times when the sun is up.

Time-of-use pricing can work for electricity consumption as well as generation on the customers' side. In order to prevent all solar customers from selling all of their generation at the same time, utilities can provide them with a rate that is less during the day (peak solar time) and higher during the evening and night. This would in turn encourage storage which would help the utilities balance demand with supply better as the sun goes down (however, utilities must be wary of customers using the stored electricity directly if it becomes so cheap). Electric Vehicles can work very well with this scheme as well. They can be charged during the day and can be used to provide electricity to the grid at a pre-determined time when supply is usually short.

3.9 Electric Vehicles

Electric vehicles (EVs) are growing in number all over the world. More and more countries are legislating for the inclusion of electric vehicles into the mix, providing subsidies in the process. Norway plans to ban sale of fossil fuel based vehicles by 2025 [7], Netherlands by 2030 [39]. India has announced to increase the share of EVs to 30% by 2030 [8].

Electric vehicles, due to their composition, provide an excellent resource of energy for the grid. Each car consists of a high quality battery pack and inverter, both of which could be used to support the grid. Moreover, charging of the batteries can be performed at times of peak supply and discharged to support the grid in times of shortage. Tesla sold more than 70,000 Model S cars in 2015 which amounts to 5 GWh of storage and 21 GW of bi-directional high quality inverters [40]. All of these can be an excellent source of providing backup and stability to the grid. Electric vehicles can also be a useful tool to solve the excess electricity problem Pakistan is expected to face by adding a significant amount of load to the mix.

3.10 Electricity Markets

Around the world, the unbundling of the energy sector has led to the creation and evolution of the wholesale market. Previously, everything was vertically integrated and state-owned with only one entity responsible for generation, transmission and distribution. With separate entities in charge of different aspects, sophisticated electricity markets have taken shape. Generally, the new market can be divided into capacity, day-ahead and frequency markets.

- In capacity markets, the grid operators buy long-term power guarantees from generators irrespective of power being needed to provide security to generators.
- In the day-ahead market, energy is purchased according to the forecasted demand for the next day. Even in this market a minimum amount of energy at certain times of the day can be booked for longer periods of time.
- Frequency markets are real-time markets in which control over a small amount of capacity can be obtained for typically 5 to 30 minutes in order to stabilize instantaneous demand and supply. This has to respond within typically 30 seconds and is the most expensive to purchase.

The next step in the electricity market is for the end-customer to have choice regarding the retailer that supplies electricity to his doorstep. This is being experimented in different regions of the world now and is expected to take shape in the next few years.

Pakistan itself has introduced the NEPRA Act 2018 in which the creation of a Competitive Trading Bilateral Contract Market (CTBCM) has been proposed by 2021. This would involve different participants including suppliers and retailers in an open market. It is explained in more detail in a later section.

3.11 Carbon Trading

In an effort to curb carbon emissions, the concept of Carbon Trading has taken shape in developed countries of the world. Under this scheme, the government issues permit to relevant companies, either free or by auction, for a certain amount of approved emissions. If the company manages to cut its emissions, it can trade the remaining permits on the market with companies that exceed their allotted emissions. This provides an incentive to companies to cut down on their emissions.

4 DISTRIBUTED GENERATION BENEFITS

Distributed generation brings with it countless benefits. Several studies have been conducted all over the world to do cost-benefit analyses of distributed solar. In a large number of studies, solar has been assigned a value higher than its retail price due to its environmental and social benefits, as mentioned below. Due to these factors, far from being net cost, solar has been seen as a net-benefit in many studies. For instance, a study by Minnesota Public Utilities Commission, in 2014, valued solar at 14.5 cents/kWh, when the retail rates were around 11 cents/kWh [28]. Although, there have been studies on the contrary like the Louisiana PUC study which found that net-metering customer did not pay the full cost of service, a review of 11 studies conducted by Environment America Research and Policy Center found distributed solar to be offering benefits to the entire electricity grid [28]. A lot of utilities over the world are now setting a compensation rate for distributed solar while factoring in the benefits that it brings to the table.

4.1 Clean Energy

Distributed solar provides clean electricity using the sun's seemingly limitless energy, which is free of cost. In today's world, with pollution levels reaching emergency levels, there is a dire need to protect the environment. Pakistan, in particular, is desperately struggling with environmental problems. Harmful pollutants in the air have far exceeded safety limits and many cities in Pakistan have been listed amongst the most polluted cities in the world. Smog, produced with the mixing of pollutants such as Carbon Dioxide, Sulphur Dioxide and Oxides of Nitrogen with the air, has emerged as a significant health hazard in many cities. Furthermore, according to Pakistan Environment Protection Agency (Pak-EPA), the levels of certain types of particulate matter (PM) in the air in Lahore far exceed the WHO specified limits. Both Lahore and Faisalabad have been named in the top 10 most polluted cities in the world [9]. Pakistan has also been listed as the seventh most vulnerable country to climate change [20].

The figures below show the concentration maps of Nitrogen Dioxide and $PM_{2.5}$. The concentration of these harmful particles has reached alarming levels, especially in urban centres of Pakistan. Pollution, with air pollution being the major culprit, accounts for over 310,000 deaths (22%) in Pakistan with many more suffering from respiratory illnesses [41]. Desperate measures must be taken in order to protect our future generations from life-threatening problems.

The major culprits in the deteriorating environmental conditions of Pakistan remain the power generation and transportation sector. A transition to renewable energy in the electricity sector can go a long way into solving the pollution and global warming issue in the country. Furthermore, if the transport sector can be electrified, it can even cut the emissions from vehicles, which could be monumental towards solving the pollution crisis Pakistan finds itself in.

A better environment results in lesser health-related costs, lesser damages to building and numerous other benefits that indirectly help in saving significant amounts of money. The avoided carbon costs and environmental compliance costs also adds additional worth to distributed solar.

4.2 Supports Grid Supply

Distributed solar helps utilities cover up for the shortfall in supply during times of peak demand. It can help utilities save costs by eliminating the need to have expensive plants operating to provide backup during times of high demand. Due to the way the electricity markets work in a lot of countries, the electricity bought by utilities to cover instant fluctuations is the most expensive. This is because these require fast-responding gas plants that are costlier. Even in Pakistan, the economic dispatch model ensures

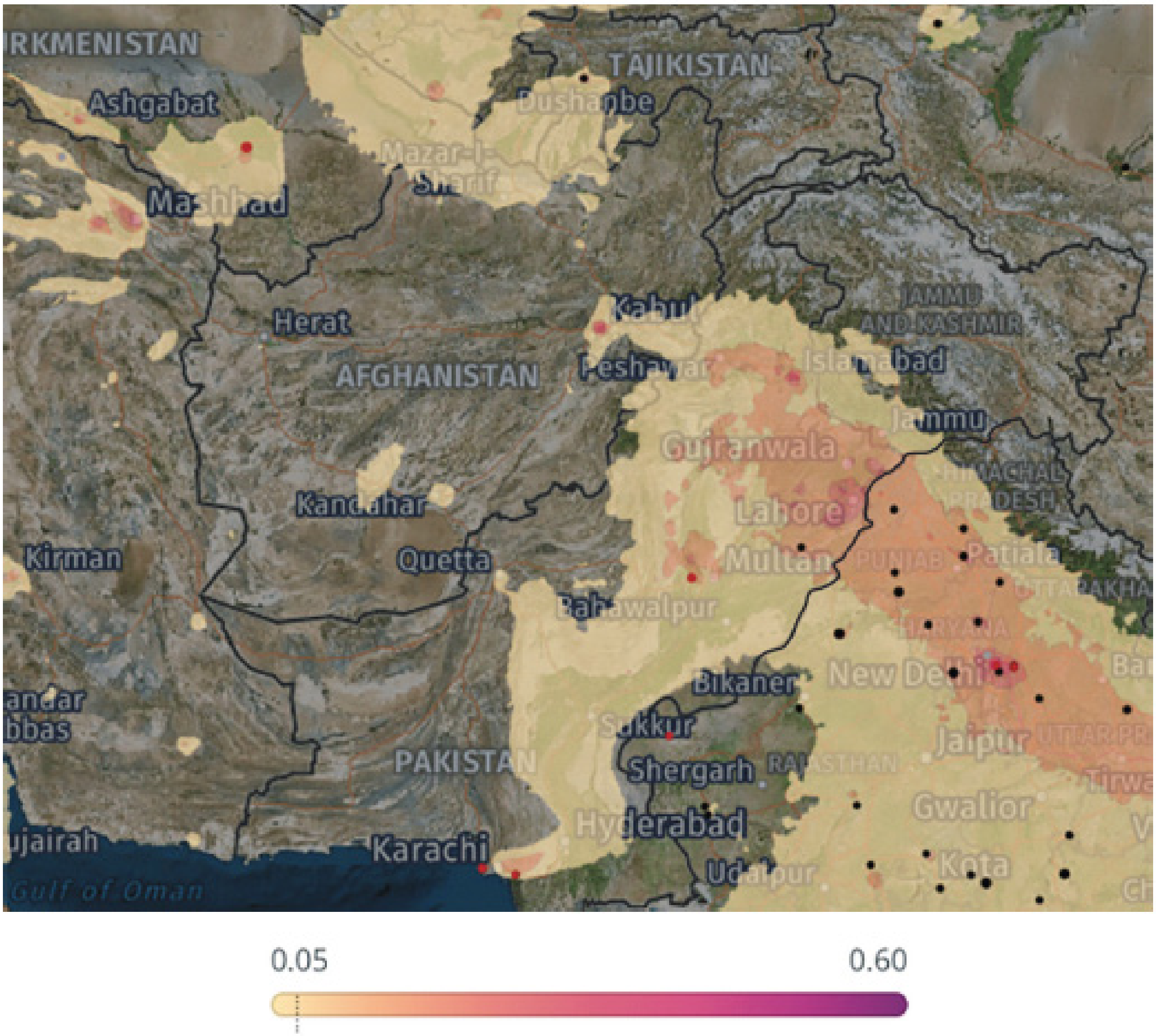

Figure 4: The concentration of NO_2 across various regions in Pakistan [42]

that cheap sources of electricity are utilized first. As demand increases, the costlier sources are added to the mix. The electricity provided by solar complements the energy provided by the utilities and helps utilities avoid purchasing expensive electricity. Furthermore, in doing so it also stabilizes the prices on the short-term electricity market.

Distributed solar also does not require contractual terms that are needed for utility-scale investors. As mentioned previously, in order to attract investors for utility-scale solar certain terms are offered that are highly in favour of the investors. For instance, any loss in production does not cost the investor anything. With utility solar, due to smaller investments, such terms are not necessary.

4.3 No Need of Additional Infrastructure

Another significant advantage of distributed generation is that there is no need for additional infrastructure. As demand increases, expensive grid updates need to be performed in order to increase the capacity of the grid. Furthermore, more generation plants need to be constructed that upset the landscape and result in controversy. More transmission and distribution lines need to be built. All these, in effect, make their way into the ratepayers' bills increasing the retail costs of electricity.

Going forward, rather than making expensive upgrades to the grid and building more transmission lines, utilities can invest in distributed solar to manage the increase in demand. With distributed solar, electricity is consumed at or around the generation site, eliminating the need for expensive upgrades.

Distributed solar can also be employed by the utilities to provide electricity to those regions which have not been connected to the grid without laying an additional network of transmission and distribution lines.

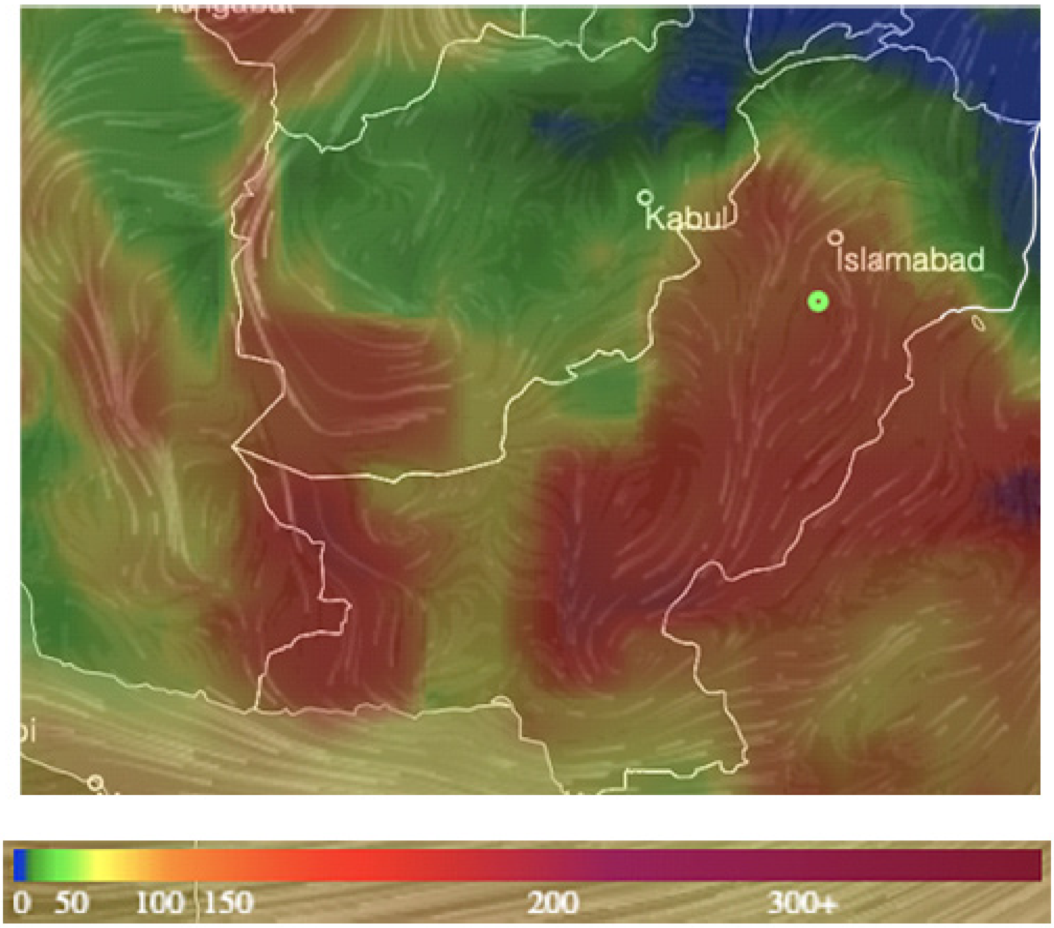

Figure 5: Concentration of $PM_{2.5}$ across various regions in Pakistan [43]

4.4 Significantly Less Losses

Due to the fact that distributed generation is located at or close to its point of consumption, it suffers from very little distribution losses which form a significant part of the traditional electricity supply. According to the latest Hydro-carbon Development Institute of Pakistan (HDIP) Report 2017, the losses in Pakistan's power systems have reached 19.8% [10]. The losses have been more pronounced because of the fact that traditional sources of power generation, by their nature, need to be situated far from urban centres. If, in the future, utilities could incorporate rooftop solar in its power mix, it could help save the utilities a lot money in terms of avoided losses.

4.5 Better Maintenance

As distributed generation inherently encourages more production, be it for self- consumption or feeding into the grid, the installers have a greater incentive to clean and maintain them for maximum production. This was one of the things China noted when it ventured into large-scale solar systems. Although, the investors had an incentive to install the system, they did not have any motivation to produce maximum power due to which they didn't maintain the systems. The same was experienced by Pakistan with the Quaid-e-Azam solar park. As the park was situated in a desert area, the sheer amount of dust covered the solar panels, rendering them inefficient. Distributed solar on the other hand, rewards installers according to its production. Furthermore, a small system managed by its actual owner is easier to maintain on a regular basis. As a result, more electricity is produced, benefitting the installer and the grid.

4.6 Grid Stability Using Inverters

Rooftop solar invariably uses inverters in order to convert the DC electricity produced from the panels into AC. These inverters have useful functionalities and can provide ancillary services to the grid in times of need. Inverters can sense the voltage levels and other parameters of the electricity on the grid and act accordingly. They are capable of operating at a variable power factor and can essentially insert reactive power on the grid in times of low voltages or absorb reactive power in case of higher voltages, as a result stabilizing the grid. Inverters can also shape the wave to the 8th harmonic, stabilizing the voltages and currents on the grid as required.

Not only do the inverters provide direct grid support but can also provide the utilities with real-time data on how well the grid is performing in a particular area. This is something being done by Enphase micro-inverters in the Hawaii grid [44]. Furthermore, analytics performed on this data can lead to enhanced capabilities like demand forecasting and fault detection that the utilities can invest into. This is a market Commonwealth Edison in US has taken a leap into [37].

5 DISTRIBUTED GENERATION CHALLENGES

While distributed generation brings with it a myriad of benefits, it is not devoid of challenges. However, these challenges are far from being unsolvable and are similar to those expected with every new technological revolution. If an approach to address these problems is developed when distributed generation is still in its infancy, it can go a long way in successfully integrating it with the utilities' structure.

5.1 Revenue Erosion for Utilities (With or Without Net- Metering)

One of the biggest obstacles in the way of distributed solar is the fact that with its increased adoption utilities' revenues decrease as solar consumers would now be using less electricity from them. This is so with or without a mechanism of feeding electricity into the grid. Furthermore, these defections are initially mainly from the good customers with a lot of electricity demand, like shopping malls, industries and universities. In Hawaii, from 2007 to 2016, utilities suffered a 21% decrease in sales [11]. US utilities are expected to lose $18 to $48 billion per year over the next decade due to rooftop solar [12]. As a result, the utilities, which in fact own the grid, have little incentive to promote distributed generation. Countless examples can be seen across the world where resistance has come from utilities against distributed solar. This resistance has usually highlighted some other challenge posed by distributed solar on the front but it cannot be ignored that the declining revenue issue is at the heart of it. Several utilities have been accused of lobbying in assemblies to have bills passed against the promotion of rooftop solar.

In Nevada, for instance, in 2015, Warren Buffett's company, NV Energy, came in the center of a storm when the state Public Utilities Commission decided to triple the service fee for rooftop solar and bring down compensation for solar energy to wholesale rates over the next twelve years. The reason given was that non-solar customers were unfairly subsidizing solar users, whereas several studies revealed otherwise [28]. Prior to this, rooftop solar had thrived in the sunny state of Nevada with rooftop solar increasing by 400% from 2014 to 2015 [45]. Warren Buffett, in a letter to investors in 2016, also wrote about the risks faced by their utilities from distributed resources [46]. There have been countless other cases such as in New South Wales, where utilities were accused of delaying rooftop solar permits by exaggerating the grid instability issue with solar in order to protect their revenues [47].

5.2 Rate Mechanism and Unfair Distribution of Fixed Costs

Another issue with rooftop solar that needs to be tackled is that of a viable compensation scheme. If the compensation is too high, the utilities stand at a disadvantage for buying expensive electricity when they could have bought cheaper at wholesale rates. On the other hand, if the compensation is too low, the incentive for installing solar dies out, although consumers can still install smaller systems for self-consumption. Solar also brings with it a lot of advantages that wholesale fossil-fuel-based electricity does not, which must be weighed into the compensation. All in all, it is a tricky situation that must be settled on a common ground.
This issue has given rise to the discussion of alternative rate structures to replace the current unit-based pricing. Most of them comprise a varying mix of fixed charges and demand charges on top of volumetric rates.

Volumetric charges, conventionally in place, are charged on the units of electricity consumed by the customer. Furthermore, if he is supplying energy to the grid, he gets compensated per unit at the rate set by the regulatory authority. Fixed charges are those that are applied to every customer who is connected to the grid.

Fixed charges essentially reflect an emphasis towards grid connection, in which connection is more important than actual consumption. They can be introduced in the face of grid defection, where customers are increasingly relying on distributed generation and are consuming lesser units from the utilities. Fixed charges bring solar customers more in parity with non-solar ones. Demand charges are applied according to the maximum demand of the customer during a month. They are introduced based on the idea that both solar and non-solar customers draw similar amounts of maximum power because when the sun is down both would draw equal amounts electricity from the grid. By throwing a charge proportional to this figure could help better allocate grid costs amongst the two groups.

Rate mechanisms have also been used by authorities to stem the growth of solar. In Hawaii, after the quick adoption of solar led to instability in the grid, the regulatory authority closed net-metering to new customers in 2015 and replaced it with two tariffs, "self-supply" and "grid-supply" [48]. With "self- supply" customers would receive an expedited review but would be restricted in supplying energy to the grid, which it would not be compensated for. Under the "grid-supply" option consumers would be able to supply energy to the grid but would be compensated at the wholesale rate, a far cry from the retail rates in net-metering. Besides, all solar customers connected to the grid would need to pay a minimum monthly bill, $25 for residential and $50 for commercial. Although, the concern about grid stability was real in the case of Hawaii as on many circuits the amount of solar had exceeded 30% of the peak load, the new rate changes were met with strong opposition. It must be noted, however, that growth of solar PV installations didn't decline, with 109MW being installed in 2017 alone [49]. This is an example of solar thriving even in the face of unfavourable polices because Hawaii, with its exorbiant electricity rates had already reached grid-parity.

5.3 Grid Instability

A genuine challenge associated with distributed solar is the fact that it can have certain undesirable effects on the grid. However, when approaching these effects two things must be kept in mind. Firstly, they only happen at high solar penetration. Secondly, with proper planning and a little bit of effort they can easily be resolved.

To understand these issues, it must be noted that with distributed generation, although electricity is supplied to the grid, this electricity can only be consumed at the local substation transformer level. It cannot travel beyond the substation transformer as it is only designed for one-way flow in radially fed systems. Once the solar systems on a particular substation transformer produce more power than is needed, the voltage levels at the transformer can rise and can potentially cause damage to the equipment [14][13][15]. It can also result in a certain amount of undesirable backfeed from the transformer that can mess up transformer line drop compensation settings for voltage control. Furthermore, if a large part of the power at a transformer is being provided through distributed solar, frequent fluctuations can cause more frequent changes to the transformer settings especially load tap changer settings, leading to greater wear and tear of the equipment. Voltage flicker due to dips in solar irradiance are also an issue at higher penetration. Lastly, inverters without ride-through capability can trip during voltage or frequency fluctuations, resulting in outages.

Although these issues exist, it has been shown that they can be solved with minimal effort and forecasting. First of all, there is a limit to the amount of rooftop solar that can be connected to the grid. Several studies have shown that the limit of 15 to 30% is more than sufficient to keep grid problems under check. In actuality, this limit can even be exceeded if solar can be better forecast and controlled using inverters. The inverters, in effect, can shape the wave up to the 8th harmonic and can also prevent solar from entering the grid if there are chances of grid instability. The ride-through capability in certain inverters to prevent it from tripping easily provides stability to the grid during voltage and frequency fluctuations. Lastly, protection relays can be introduced to prevent energy from being fed into the grid at undesirable times.

This problem was predominant in Hawaii where electricity rates are exorbitantly high. As a result, people rushed to install rooftop solar due to which the limit of solar on certain feeders was reached [50]. Permits had to be delayed in some cases for more than a year. Subsequently, in order to stabilize the growth of solar, the regulatory authorities closed net-metering to new customers in 2015 and replaced it with two tariffs as mentioned above. Furthermore, HECO, the utility, announced plans on upgrading the grid. As opposed to only investing in the hardware, this time they planned to focus more on the software side of things. Smart meters were planned to be deployed with solar customers in dense solar areas with advanced software to make better usage decisions. Furthermore, fault-detecting devices would be deployed on the utility side of the meter along with more volt-var controllers on the grid. HECO also plans to make more use of inverters to provide grid stability with their ride-through functionality and the ability to provide reactive power. It also plans to make use of time-of-use pricing to better manage the excess rooftop solar. All of these together could help them absorb three times the existing solar energy into the grid [51].

Lastly, on the topic of stability and security, it is very important that solar installations be islanded from the grid during outages or maintenance. If that is not done, electricity might be inducted into the grid during these times causing damage to the equipment and creating life hazard for the linemen. This problem is more profound in Pakistan where typically, the ground line is not properly connected. Proper disconnection from the grid during outages must also be put into legislation to prevent disasters and fatalities from happening.

5.4 Demand-Supply Matching

This issue is related to the unpredictability of solar energy and other renewable resources. As more and more distributed systems get connected to the grid it gets harder for utilities to predict their generation and match demand accurately. This is because solar irradiance at a particular location can get affected by factors such as cloud cover and fog. However, this problem can be tackled in a variety of ways. On cloudy or foggy days, sufficient backup power provided by conventional sources can be kept at hand. Sufficient amounts of battery storage can be adopted. Better forecasting can be performed aided by real-time data from solar installations.

It is pertinent to mention that this issue is less of a problem with Pakistan with predominantly sunny days throughout the year.

5.5 The 'Duck Curve' Problem

The Duck Curve problem was first raised in a report in 2013 by California Independent System Operator (CAISO) [52]. Basically, this problem is not specifically a distributed solar problem but a solar problem in general. This is different from the grid instability problem mentioned earlier which was only at the substation transformer level due to distributed generation. The Duck Curve problem pertains to penetration of solar in the overall distribution system that includes distributed solar and utility scale solar installations. Nevertheless, it is an important problem that must be mentioned as it is bound to appear as solar-based electricity increases in the mix.

The Duck Curve problem is illustrated in the figure below. As increasing amounts of solar get added, during the day, an excessive amount of solar-based electricity would be produced. To prevent oversupply of electricity, as electricity supply must match demand at all times - many conventional power plants would need to be turned off. However, as the sun goes down and solar energy starts to fall rapidly, conventional generation would need to ramp up quickly to meet demand. The problem is that, generally, conventional generation does not have the capability to ramp up so fast, except for hydro power and certain natural gas plants. This means that at the time of peak solar generation, these plants need to provide a certain minimum amount of power in order to ramp up in time to meet the evening demand. This means that a minimum amount of conventional generation would always be needed, limiting the amount of solar penetration in the system. Furthermore, some conventional plants are always required to be on during the day time to provide backup in case of fluctuations in solar energy as well as frequency control which further limit the amount of solar than can be added to the system. As a result, the maximum amount of solar the system can handle is limited and the excess would need to be curtailed or managed in another way. Studies show that a maximum of around 20% of solar in the grid (in terms of energy not capacity) can be handled without significant curtailment. Regions with high solar penetration like California and Germany have had to sell electricity at negative prices due to this problem which must be planned for ahead of time.

It is to be noted that with Pakistan's electricity grid the onset of the Duck Curve problem might appear earlier than the 20% figure for developed countries. This is because Pakistan might not have as much ramping up capability and storage available to quickly cover up for the evening demand. Studies must be conducted to get an idea of the impact of the Duck

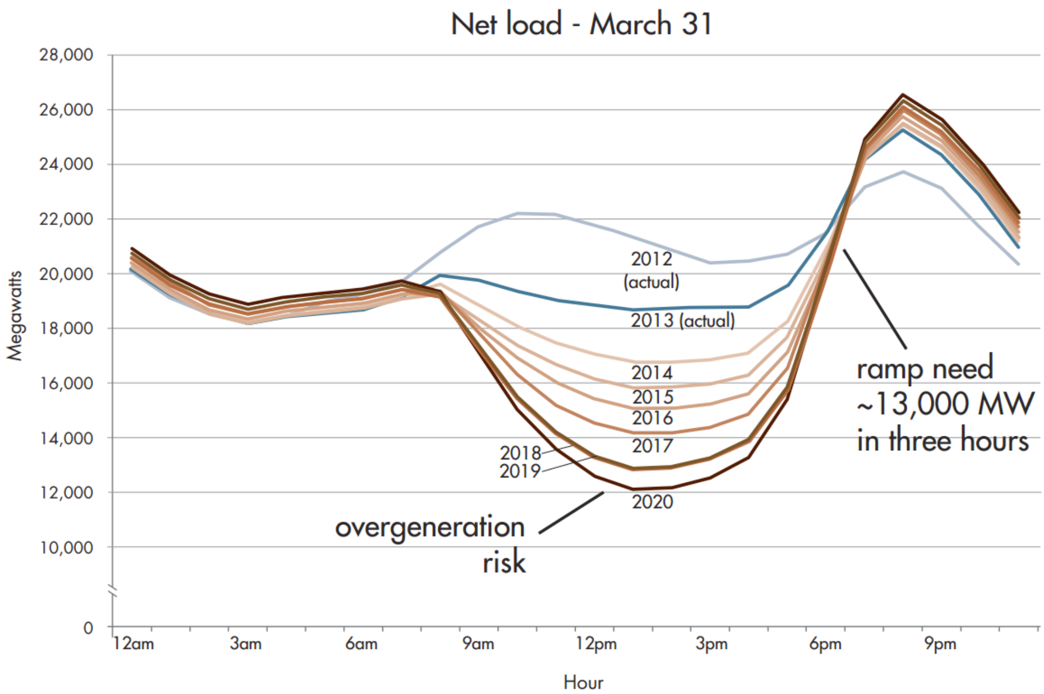

Figure 6: The CAISO Duck Curve [52]

Curve considering Pakistan's demand curves and generation mix.

The Duck Curve problem is essentially a problem of there being minimum conventional generation during the day limiting the amount of solar energy on the grid. Below a certain percentage of solar, this problem does not occur. There are certain ways in which this problem can be mitigated:

- Investing in storage which can provide backup as well as shift load
- Investing in fast-responsive natural gas plants which are expensive
- Demand-side management to increase load during peak solar hours
- Using electric vehicles that charge during the day and supply energy during the evening
- Exporting electricity to neighbouring regions

It must be noted that the Duck Curve is a problem that occurs at a very advanced stage of solar penetration, when the combined generation has a significant chunk from renewable sources (around 20%). Rooftop solar is unlikely to alone cause the duck curve problem. However, this problem must be planned for because solar in general is expected to be a big player in the energy mix in the future. More visibility into and control of solar installations should definitely assist in alleviating this problem.

6 CURRENT UTILITY MODEL AND ELECTRICITY SITUATION IN PAKISTAN

Around the late 1980's and early 1990's, all over the world, the electricity sector experienced a wave of restructuring. Initially, the utility model was a monopoly model, where the government owned everything. The first wave of restructuring saw the unbundling of distribution from generation and transmission followed by privatization in the generation side. Now, the electricity sector is moving towards a retail market, where there would be numerous buyers and sellers and customers would have the options of subscribing to the utility of their choice.

In Pakistan, following partition, the entire electricity infrastructure was in the hands of the public sector. However, in the early 90's, following the global drive towards unbundling the power sector, reforms were introduced to do the same. The Strategic Plan for Restructuring the Pakistan Power Sector was introduced. Under these reforms, the power sector was split in various entities, with WAPDA only being responsible for hydro power. Generation companies (GENCOs) and independent power producers (IPPs) were responsible, along with WAPDA, for generation. National Transmission and Despatch Company (NTDC) was created to oversee transmission. The National Power Control Center (NPCC) was to manage voltage and frequency control of the transmission grid as well as match demand with supply. On the distribution side, 9 distribution companies (DISCOs) were created to distribute power to the customer. A separate independent body, National Electricity and Power Regulatory Authority (NEPRA) was formed to oversee fairness among various stakeholders. Central Power Purchase Agency (CPPA) was made responsible for the purchasing of wholesale power and selling it to the distribution companies. It is to be noted that apart from the IPPs, all the entities involved are state-owned. Apart from that K-Electric is the only privately-owned vertically-integrated utility in Pakistan with its own mandate. It purchases power from the CPPA like other utilities.

This is how things stand in Pakistan today. In order to purchase electricity, the DISCOs communicate their demand to the NTDC. The NPCC allots power to the Discos from various generation sources according to an economic merit order on a daily basis. The economic merit order lists the available generation sources according to their costs. The cheapest sources are utilized first and the transactions are made through the CPPA. The generation companies get paid according to the electricity they supply. Besides that, in order to provide them with incentive to invest, they are bound to be paid capacity payments even if they don't supply any electricity.

In the late 2000's and early 2010's, Pakistan suffered a lot of electricity shortage. As a result, long hours of load-shedding were experienced even in major cities of the country. In order to correct that, a large number of power plants were commissioned. Commissioning of so many plants led to overcompensation, so much so that Pakistan now faces an electricity supply glut for the next several years. Already, the installed capacity of 33,000 MW in 2017 was more than the demand which varied from 8,000 to 26,000 MW during the year. By 2025, the peak generation capacity is going to become around 62,000 MW while the demand might touch 40,000 MW. In 2018-19, Pakistan is expected to use 128 TWh out of the 169 TWh generation capability, with capacity payments amounting to 664 billion Rs of which 162 bn would be for idle capacity. If things don't change, capacity payments will reach around 1500 billion Rs by 2025. Furthermore, with distributed generation gathering pace, the supply would even exceed this figure. It is expected that by 2022, the total amount of rooftop solar may touch 5 GW [6]. This would lead to even more unutilized energy.

Serious planning is required in the energy sector to absorb this excess power as well as accommodate rooftop solar into the overall scheme of things. If necessary planning is not performed at this time, due to the enormity of the situation, things could get out of hands very easily. In 2017, 950 MW worth solar panels were imported, more than the last four years combined. In a nascent market, it is only expected to grow. Furthermore, it must be kept in mind that rooftop solar looks set to stay. It has now reached a stage where it can proliferate solely based on favourable economics like in Hawaii. Considering the issues that unmonitored rooftop solar can cause, it is imperative to integrate it somehow in the utilities model so that its growth can be guided and the energy from rooftop installations be better controlled. In the next section, we present a proposed model for utilities going forward as well as recommendations on how to approach rooftop solar.

7 FUTURE UTILITY MODEL

It is clear from the above discussion that utilities need to evolve to protect their business. This is also good for the electricity sector. Utilities, with all their experience and capabilities, form the backbone of the electricity sector. Healthy utilities are essential for a stable and secure distribution of power. Hence, a future in which the utilities can live in harmony with the latest disruptions, especially distributed solar, is essential.

7.1 Upcoming legislations and opportunities

It is pertinent to mention that there is an important development taking place in the power sector in the near future that can be leveraged for this purpose. According to the NEPRA Act 2018, by early 2021, distribution companies are going to be separated into retailer companies and companies owning the wires and infrastructure. The role of the retailer companies would be simply to purchase power from the cheapest sources, pay the wire companies the fee for wheeling that electricity and charge customers for the electricity they supply. The inherent advantage of this division would be that the retailers would have no other worry but to focus on the business side of things. It would be an ideal time for them to reinvent themselves taking into account the new disruptions in the power sector.

7.2 Need to reinvent

The retailer side of utilities would need to engage customers in the future and offer tailor-made packages according to their needs. Interacting directly with customers has never been the forte of utility companies, unlike some other businesses like the telecomm sector. The only regular interaction the customers have with utilities is when they get their electricity bills. Customers usually have zero choice in the service they receive, unlike the telecomm sector where there are loads of customer-oriented packages that people can choose from. As a result, the perception of utilities among customers has also not been very favourable for one reason or another.

The utilities, in the future, would need to change all this. They would need to have better customer relationship, tailor different packages for different kinds of customers and improve their perception among people. These are some of the aspects utilities can look into:

- With so much in the mix like distributed solar, demand-side management, electric vehicles, etc, different rate schemes can be designed to optimize energy use, maximize profits and satisfy customers.
- Within distributed solar, for instance, to promote storage, an option can be provided of higher compensation rates during the evening and lower during the day.
- In demand-side management, customers could sign into a utility program in which they would reduce a certain amount of their load upon a message from the utilities in return for benefits.
- Programs for EV charging could be designed where customers would have incentive to charge (or discharge) their batteries at times when it would most benefit the grid.

However, as mentioned above, utilities tend to be weak in this front. A lot of effort would be required from them, an impetus for which could be provided by the restructuring of the distribution companies. Large scale advertising and marketing would need to be performed to reach out to every customer, similar to the way telecomm companies operate.

7.3 Recommendations

In light of the benefits and challenges of distributed solar, as well as the upcomming legislation in hte power sector, we have proposed the following recommendations for the power sector going forward, keeping in mind the experiences of other regions with distributed solar. It is hoped that they would be beneficial in ensuring a smooth transition to the power grid of the future.

Overcoming the basic utility revenue problem

The problem of utilities losing out on revenues is a big problem, as mentioned above. Being the backbone of the power system, they cannot be allowed to lose interest in the effort towards clean energy. Taking into account the approaches taken in different regions, we propose three approaches by which this could be done: utility ownership of solar systems, a buy-all-sell-all policy and revamping of building mechanism.

- Utilities may partner with third parties in much the same way as individuals today partner with third parties. Utilities can purchase electricity from these third parties and sell to customers at a profit, with the installation getting transferred to the utilities at the end of a certain period. This arrangement would also be preferable for third parties as they would not have to worry about defaulting because they would be doing business with an established organisation. The utilities in turn, would not have to worry about the installation and maintenance of system.

As for the systems, they could be installed on homes of individuals who agree with it. They could be compensated in the form of rent and/or reduced electricity rates for a certain period of time. The Arizona Public Service actually proposed a plan in 2014 to install 3000 solar installations on customer's roof, paying them a

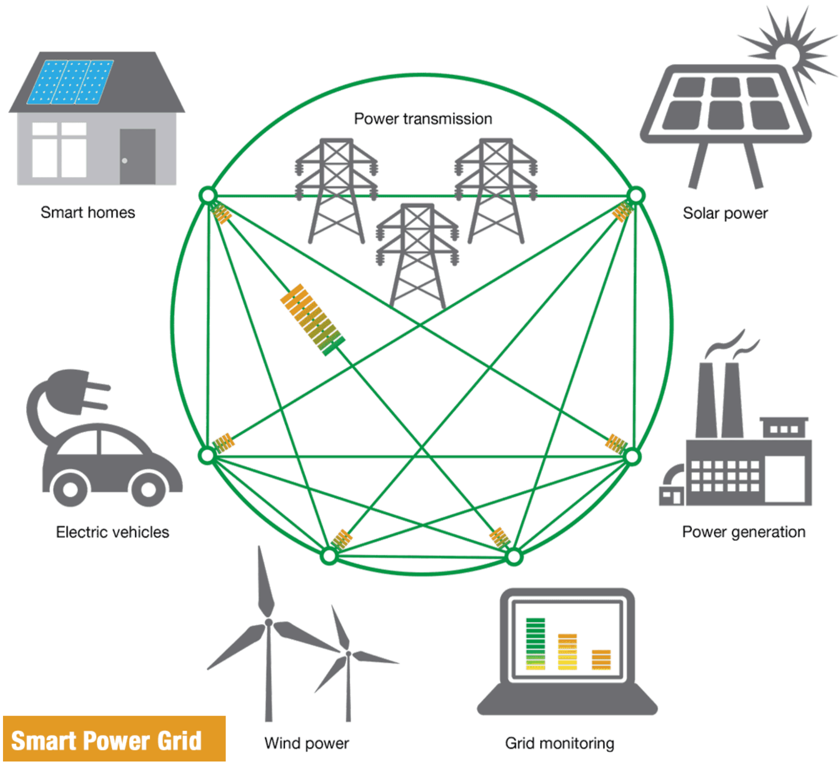

Figure 9: Future power grid [55]

rent of $30 per month.

Under this scheme, customers who install solar outside the bracket of utilities should have to pay a fixed fee if they also wish to remain connected to the grid. Partial grid defection should be discouraged. As full grid defection is far from being economical at the moment, utilities must blend in and take control before it does.

- ### Approach 1: Utility ownership

Utility ownership in itself can be implemented in the following ways:

- Utilities can build and own complete systems on homeowner' rooftops and adjust the costs in the electricity rates.

Utility ownership of solar installations would also have the following benefits that would mitigate a lot of challenges distributed solar brings:

- The inverters of all solar installations would be centrally controlled, getting adjusted according to the need of the hour. This would allow for better grid stability as inverters can provide certain essential grid services as mentioned above. HECO in Hawaii employed this successfully with the help of Enphase micro-inverters.
- It would allow for the distributed solar installations to be guided and controlled by a central authority, preventing a haphazard growth of rooftop solar leading to grid instability. Solar installations would be approved keeping in view the situation of the grid. Better quality inverters may be required for more congested areas.
- Installations would be encouraged in areas where they are more needed. The feed-in tariff can be varied to engage more customers and vice versa.
- The utilities would have real-time data of production from distributed sources allowing it to better meet supply with demand as well as forecast demand.

All these factors would play their role in bringing the best out of distributed solar for all the stakeholders involved.

- Approach 2: Buy-all-sell-all

If the utilities don't go into owning rooftop solar, alternatively, customers who install solar could be incentivized to sell all the solar they produce to the utilities at rates less that retail prices but higher than wholesale rate. If in addition to this, they want to consume as well they would be paid minimal compensation for it or a significant fee. This was done in Hawaii following the massive uptake of rooftop solar by their citizens.

The concept behind this approach is that in this way the solar customers will be just like another supply source for the utility which it would be selling at with a profit margin. When the utilities get bypassed completely, that is when it becomes a revenue problem for the utilities. By not self-consuming, the customers would not be cutting into the revenues of the utilities. The utilities would also be able to appreciate the wide benefits that rooftop solar offers and would want to encourage its growth. On the other side, the customers as well would need to be given a viable incentive to prevent them from consuming the energy from their installations. The government can step in here as well to support the utilities as the strength of the utilities is a benefit for the country.

- Approach 3: Revamping of billing mechanisms

In the face of consumers becoming "prosumers", the billing mechanism must be revamped. Going forward, utilities must separate revenues from units of energy as their ultimate goal is revenue not production. The electricity grid involves a majority of fixed costs in the form of huge infrastructure but fixed charges form an insignificant portion of the bill which is calculated on the basis of units consumed. There are three main things that the utilities can do:

- Fixed chargers can be made use of as done in several states around the world. As the connection to the grid might be of more value in the future than actual units consumed, the unit-based rate can be lowered and fixed charges according to usage. However, now, with distributed solar, a lot of customers might not be paying their fair share of fixed costs due to less usage even through they are using the grid for consumption as well as feeding in electricity.
- Instead of net-metering, a less than retail rate feed-in tariff should be introduced to allow utilities to make profit out of the purchased electricity. Net-metering has now become an obsolete program due to decreased costs for solar, intended for initial solar uptake which is not needed now.
- Demand chargers, based on maximum demand in a certain time interval over a month, can be introduced to even out costs between solar and non-solar customers. This is because the capacity has to be built for the maximum load even if the customer consumes less overall units. This is more similar in nature to the fixed cost division today in which those who stress the grid more, pay higher bills.

Rooftop solar feasibility studies

Feasibility studies should be conducted at selected typical feeders to get an idea of the amount of solar that can be added to local feeders across Pakistan. Detailed studies should be conducted on specific feeders where rooftop solar nears the maximum limit. There have been examples of several studies conducted across the world that can be made use of. A study in Malaysia in specific used the DigSILENT Power Factory software to determine the maximum PV penetration on an actual grid [54]. More advanced studies have also been done like the NREL study on 16 US feeders using GridLAB-D[13].

Introduction of time-of-use pricing

The utilities must also look into time-of-use pricing. With distributed solar, in particular, the value of electricity cannot be separated from time. As there are so much factors into play now with demand-side management, storage and EVs adding a further twist to the tale, pricing can be experimented with to better utilize the available resources.

- On the solar compensation side, more value can be provided to times in which the grid needs energy the most.
- Tailor-made programs for EVs can be introduced for EV owners providing them favourable rates to charge and possibly discharge when most suitable for the grid.
- Storage can be encouraged by offering better compensation rates in the evening when the sun is going down in order to mitigate the Duck Curve problem. However, utilities must be wary of storage on the customer end if it gets so cheap.
- Instead of having only "peak" and "off-peak" times, more time intervals can be introduced according to demand-supply dynamics.
- In the future, a mechanism closer to real-time pricing can be introduced to effectivily implement demand-side management.

Storage solutions

In the future, utilities can employ storage to their benefit. As it is getting cheaper, it can replace expensive plants needed as backup in case of high demand. Storage can be used in the following ways:

- It can provide backup power, in which case it would be like another supply source in the CTBCM. This works ideally with more and more renewables getting added to the mix and would also provide a buffer against the 'Duck Curve' problem.
- It can provide instantaneous grid stability in response to fluctuations in power. This is also known as ancillary services. In more advanced markets these are traded as very expensive sources of electricity.
- It can be situated at a smaller scale at transformer level in areas where excess solar is expected to store it during the day and provide it in the evening or night time. This can be provided as a service to the neighbourhood. This would also prevent customers from investing in storage themselves that can be detrimental to the utilities.

The examples of utilities working with storage mentioned in this report as well as many others around the world should inspire utilities into employing storage in their mix.

Data analytics

Furthermore, utilities need to take the lead in investing into the huge data analytics market emerging out of electricity data. With minimal investment, real-time data of energy consumption of actual households can be obtained by the utilities. Information obtained from this can be used by utilities in a number of ways:

- Energy efficiency programs can be introduced to customers to reduce their electricity consumption. Research today has advanced to a stage where use of individual appliances can even be extracted from consumption data. If time-of use pricing is introduced, this feature would provide a lot a value to customers.
- Data from devices on equipments can be used to monitor equipment health and wear and tear. It can help utilities in asset management as in the case of Commonwealth Edison mentioned above.
- Faults and demand-supply mismatches can be predicted in advance using pattern recognition to prevent power outages and fluctuations.
- Electricity theft can be detected using data analytics, which would be a great plus for utilities. However, for that utilities must be incentivised to minimize theft on their systems, something that is not currently in place.

Incentivizing of clean energy

Down the road, the government should also step in and incentivize distributed solar. This should be done to integrate more renewable generation sources into the mix due to the appalling environmental condition in Pakistan. This can be done in various ways listed below:

- Tax credits can be offered to people who partner with utilities to install rooftop solar
- Renewable energy targets can be set for utilities in which they would have to procure electricity from renewable sources. Failure to do so would result in penalties.
- Pilot or demonstration projects can be arranged to increase acceptability among masses.
- Carbon trading can be made use of at a general level in which businesses would be allowed a certain amount of emissions according to their scope which they could trade with other businesses.

All these recommendations might seem remote from how utilities have operated in past but reinvention is exactly what is required from the part of the utilities. Once utilities start to engage with their customers the way telecomm companies do today, such innovations would not seem far-fetched.

It must be mentioned here that although a lot of these recommendations might seem to have a bias towards utilities, that is not the case. The purpose of this report is to provide a way for the future in which the utilities can coexist with the new developments in power sector, something that would benefit every stakeholder involved. A planned and well-controlled grid is in everybody's favour in the long run. The government must also appreciate this and not let the utilities fall into a death spiral. If need be, it can actually help the utilities cope with these disruptions for a certain period of time to provide them security and allow them to restructure themselves. Once they are on track with a viable business model, they should be able to sustain themselves and continue to add value to the overall scheme of things.

8 CONCLUSION

In conclusion, it must be said that although distributed solar is beneficial for the electricity sector and the environment, it must be approached with care, taking into account other countries' experiences. As rooftop solar is starting to pick up pace in Pakistan, now is the critical time to plan its growth and to shape the business model utilities are going to adopt around it. If this is not done now, certain issues are bound to appear sooner or later that can jeopardize the move towards clean renewable energy in Pakistan. In this report we have talked about the new innovations in the electricity sector that the utilities need to consider moving forward as the consumers of the past are becoming "prosumers" of the future. We have also discussed the benefits and challenges of distributed solar in light of other countries' experiences and have proposed certain recommendations that can be used to guide the policy on distributed solar.

In a nutshell, utilities' revenue erosion, unfair distribution of fixed costs among non-solar customers and grid stability concerns are some of the major issues that must be resolved before diving head-on into rooftop solar. The utilities, on their part, must reinvent to absorb the new innovations taking place in the energy sector before it is too late. Some kind of rooftop solar ownership, utilization of storage and time-of-use pricing, and offering of customer-oriented energy-related services is on the cards for them. It is hoped that this report can be beneficial in Pakistan's transition towards the grid of the future, in particular rooftop solar. There is no doubt that if rooftop solar is intelligently utilized and carefully planned for, it can be a win-win for Pakistan and all the stakeholders involved.

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ہیں تیرے تصرّف میں یہ بادل، یہ گھٹائیں
یہ گنبدِ افلاک، یہ خاموش فضائیں

یہ کوہ یہ صحرا، یہ سمندر یہ ہوائیں
تھیں پیشِ نظر کل تو فرشتوں کی ادائیں

آئینۂ ایّام میں آج اپنی ادا دیکھ!

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