Assessing Industrial Energy Transition in the Textile Sector in Pakistan

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April 22nd, 2022

Master's Project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment, Duke University
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Executive Summary

This study assesses the industrial captive power generation in Pakistan and its on-going transition to renewable energy. By focusing on the textile sector and conducting an energy survey with detailed interview sessions with energy management teams from a number of large textile companies, we try to answer some of these questions: Why do industries in Pakistan continue to generate captive power even when there is excess generation capacity in the grid, and the government is incentivizing and encouraging the use of grid electricity? What are some factors driving the transition to renewable energy in captive generation? Similarly, what are some barriers for industries to integrate renewable energy in their energy mix? What benefits, in terms of emission reductions and cost savings can be attributed by adding solar PV for these industries? Lastly, we assess the impact of a recently implemented sales taxes on renewable energy equipment on the costs of industrial solar PV projects.

Major lessons from the study include:

- Captive power generation is used more by the industry than the grid.
- Industries do not use the electricity grid because subsidy on natural gas makes the grid uneconomic as compared to captive power generation and because the grid is unreliable and fluctuations in voltages and power supply cause significant disruptions to operations and expensive machinery.
- The government continues to give a dual subsidy to the consumers – on one hand it continues to pay for idle capacity lying on the grid and on the other hand it also pays for the subsidized natural gas rates to the industry.
- Solar-PV is the cheapest source of electricity in captive generation. It is cheaper than both the grid and subsidized natural gas. The LCOE for Solar-PV in EPC projects is as low as 1.6 US cents per kWh.
- Biomass is also a low-cost captive generation fuel, but it is heavily underexploited.
- Captive Solar-PV is on the rise in the industry with most surveyed companies already generating electricity from solar-PV in their captive generation mix.
- The State Bank of Pakistan’s RE Financing Scheme has been a success with the industry. About 50% of the companies that had Solar-PV in their captive generation had gotten financing through this scheme.
- Solar-PV addition in captive mix is a way for companies to reduce their emissions while making profits. For large manufacturing companies, the IRR is 22% for investment in a captive solar-PV project that offsets 8-10% of their generation from natural gas.
- The recently implemented general sales tax of 17% on renewable energy equipment in January 2022 is not going to impact these captive Solar-PV projects significantly.
- Net-Zero targets across domestic and international supply chains are effective in driving manufacturing industries to decarbonize their processes and reduce emissions.
Our recommendations include:

- An evaluation of the dual costs to the taxpayer for idle generation capacity payments on the grid and subsidy on natural gas that go against each other.
- Cost-benefit analysis of upgradation of the transmission and distribution infrastructure versus the subsidy on captive generation fuels to the industry.
- Documenting the entire captive generation capacity in the industry by forming a centralized database with publicly available data for planning and forecasting purposes in the power sector.
- Sustaining the growth in industrial transition to renewables by continuing SBP’s financing scheme beyond its current term, enabling policies for intra-DISCO wheeling rate structures, and renewable energy credits (RECs).
- The potential for biomass as a renewable energy resource for the industry should be evaluated. A commercial supply chain for several types of biomasses should be looked into from both the public and private sectors. Such a supply chain can potentially avert problems of seasonal availability and access for different industries.
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Background Information

A global transition to reduce emissions is hinged on energy transition across all regions and especially the developing ones as most of the industrial emissions in the next decades are likely to come from there [1]. This becomes more important for countries such as Pakistan where the degrading air quality levels continue to cause significant health damage to some of the most populated regions on the planet. It can be argued that economies like Pakistan’s do not necessarily have to follow the historical path of other developed nations to achieve transition because of the availability of cheaper and more accessible cleaner technologies now [2]. Even then, very little is known about the barriers to clean energy transition in developing countries [3]. Pakistan, home to 220 million people and an emerging economy, is currently undergoing an energy transition through growth in distributed energy resources across commercial, industrial, and residential sectors. This is because of its close proximity and trade relations with China, in addition to a duty-free tax regime on the import of all renewable energy equipment for the last few years that lasted till January 2022. According to the Pakistan Solar Association, solar PV equipment for about 2.8 GW capacity was imported in Pakistan during the year 2021 [4] – a year of slow post pandemic growth.

Pakistan’s industrial output is part of the broader global supply chains including textile, cement, food and dairy products, surgical instruments, and sports goods etc. Net-Zero transition commitments and global emission reduction initiatives have a direct bearing on, and from these industrial operations. The decarbonization challenge becomes more complicated in Pakistan’s industrial sectors because the bulk of the industry does not meet its electricity needs from the grid but instead uses captive power generation which is further described in the section on captive generation. A captive power generation asset is defined as a generator that produces power to meet the energy needs of a commercial or industrial consumer. A captive power generator is usually located on-site. Instead of supplying power to the larger grid outside the factory, it is consumed within the industrial premises for powering operations – hence named ‘captive’.

This industrial captive power generation sector is transitioning to renewable energy across all industrial sectors [5]. To date, however, there hasn’t been a concerted effort to keep track of this transition, to assess the drivers and barriers surrounding it, and potential impacts in terms of energy savings, emission reductions, and energy supply reliability. Because the industrial captive generation sector is undocumented, so is this transition to clean energy pertaining to it. This is because industries do not need any approval from NEPRA for any off-grid captive generation resource.
Our primary motivation behind conducting this research is to assess this industrial captive power generation and its on-going transition to renewable energy. By focusing on the textile sector and conducting an energy survey with detailed interview sessions with the energy management teams from a number of large textile companies, we try to answer some of these questions: Why do industries in Pakistan continue to generate captive power even when there is excess generation capacity in the grid, and the government is incentivizing and encouraging the use of grid electricity [6]? What are some factors driving the transition to renewable energy in captive generation? Similarly, what are some barriers for industries to integrate renewable energy in their energy mix? What benefits, in terms of emission reductions and cost savings can be attributed by adding solar PV for these industries? Lastly, we assessed the impact of a recently implemented sales taxes on renewable energy equipment on the costs of industrial solar PV projects.

About Pakistan Environment Trust and Net Zero Pakistan

This research project was undertaken in collaboration with Pakistan Environment Trust, a non-profit organization working on mobilizing global capital to solve Pakistan’s toughest environmental challenges. PET is leading Net-Zero Pakistan, a national coalition of private sector industrial players to commit to the goal of decarbonization by the year 2050. The goals of this project align with NZP’s mandate and will potentially provide much needed insights in the grey area of industrial captive generation and charting out decarbonizing pathways for Pakistan’s industrial sectors.

PET’s Net-Zero Pakistan supported this project from the very start, by contributing to the research objectives, assisting in designing industrial surveys, establishing contact with government agencies, industrial associations, and most importantly by providing access to their Net-Zero industrial partners for the purpose of conducting detailed interview sessions with their energy management teams. I am immensely grateful to Wardah Zaman, Saad Latif, and Hasan Anwer from PET for collaborating on this research and providing their invaluable assistance and advice wherever I needed it. Their help made this report possible and this entire process smooth for me, even with a time-difference of 10 hours between USA and Pakistan.

Pakistan’s Electricity Sector Structure

Pakistan’s electricity sector is significantly regulated with one national regulator (National Electric Power Regulatory Authority), twelve state owned distribution companies (DISCOs) and one private investor owned vertically integrated utility in the metropolitan area of Karachi, called K-Electric. Transmission is publicly owned and operated through the National Transmission and
Dispatch Company (NTDC) except for K-Electric while generation is open for independent power producers subject to approval and tariff regulation by NEPRA. Figure-1 shows a simplified version of the regulatory structure with various entities:

On the generation end, Pakistan has an overall generation capacity of 39.7 GW [7] with the breakdown given in Figure-2.

Another important aspect of the electricity sector is to understand how electricity demand and supply has evolved in the past few decades. As shown in Figure-3, the years between 2005 and
2018 saw a supply deficit in the face of increasing demand. During this time the grid became increasingly unreliable with power cuts (also called load-shedding) rising as much as 27% of the total demand [8]. This pushed the residential consumers to resort to installing storage systems to curtail the effects of power cuts by using UPS (Uninterrupted Power Supply systems) [9] whereas the industrial power consumer base moved to generating its own power to meet its energy needs – also called captive power.

![Diagram of available generation capacity and maximum load on the grid over the years. Source: NEPRA, State of Industry Reports](image)

While the generation capacity has been drastically increased in the last 5 years and is set to increase to 57 GW by 2030 with the generation projects already committed, the annual demand right now peaks at 25 GW [10] during summer months and is projected to peak to 32-36 GW by the year 2050 [11]. This current and projected supply surplus is caused by a host of factors including transmission and distribution bottlenecks, and demand on the grid not catching up with supply. This idle capacity causes massive financial deficit owing to committed capacity payments and adds to Pakistan’s perpetual circular debt [12]. Industrial captive power generation is also a major reason behind unutilized grid capacity, with the total captive power generation approximated to be 22.5% of the total power supplied to the industry through the grid [6].
Industrial Captive Generation and Energy Transition

Captive generation and consumption in Pakistan

Due to historical unreliability and demand-supply imbalance in Pakistan’s electricity grid, most of the industrial sector has evolved to meet its energy needs with on-site captive power generation [13]. This is especially true for manufacturing or complex industrial sectors requiring a smooth and uninterrupted supply of electricity for their operations. Industrial captive generation is based on fossil fuels including natural gas, coal, oil, and diesel in some cases. Industries continue to possess grid electricity connections where possible while using their own generators to meet their operational energy needs. Our research shows that grid connections are mostly kept for backup purposes and not used during normal operations. The government, in a bid to enhance Pakistan’s export sector competitiveness, provides subsidized natural gas at $9/MMBtu for captive power and heat generation along with a subsidized electricity rate at 9.5 US cents per kWh. Textile sector is a major receiver of this subsidy.

Energy Transition and C&I Solar PV Developer Industry

Recently, with the growth in distributed energy resources and C&I Solar PV industry in Pakistan, there is an emerging trend where the industrial sector is rapidly adding renewable energy in their captive generation mixes [5]. According to the Pakistan Solar Association, solar PV equipment for about 2.8 GW capacity was imported in Pakistan during the year 2021 [4] – a year of slow post pandemic growth. This transition is the central focus of this research which aims to assess this shift in energy mix.

Since the year 2016, the State Bank of Pakistan has been running the SBP Financing Scheme for Renewable Energy that enables financing for renewable energy projects at low interest rates [14]. The scheme is set to expire on June 30, 2022. The scheme has attracted praise for increasing the pace of renewable energy share in distributed energy resources both in the domestic and C&I sectors. The government of Pakistan also gives a subsidized flat rate of natural gas for captive power generation to manufacturing industries that export [15]. In December 2021, the flat rate was increased from 6.5 $/MMBtu to 9 $/MMBtu. This subsidy on natural gas has been a bone of contention between successive governments’ economic plans and the industrial lobbies. With domestic natural gas reserves depleting rapidly and LNG imports faced with numerous complications, the long-term availability of natural gas is seeing uncertainty which makes the prospect of industrial captive generation unreliable and uncertain [16].
Data Collection

Absence of a database

Captive power generation that is not tied to the national grid and that is not sold to a third party does not require any generation license. For this reason, the industrial captive generation capacity in Pakistan is almost completely undocumented. There is no database that documents the types of captive generation assets used by factories in different industrial sectors, their fuel requirements, or efficiencies etc. No research work has been done to this day that tries to assess this or document this generation capacity. After this was abundantly clear from the initial literature review, the next logical step in this study was to elicit the data from the industry.

Industrial sector in focus: Textile

After numerous discussions with PET, relevant government organizations and industrial associations, we decided to narrow our industrial scope to the textile sector to draw insights both specific to this sector and to the overall manufacturing industry in Pakistan. This is because the textile sector is more organized, has more data available than other large sectors, and most importantly, works closely with Pakistan Environment Trust’s Net Zero Coalition i.e., more than 90% of NZP coalition members are large textile exporting companies [17].

Textile is the most important manufacturing sector in Pakistan with the longest production chain, contributing to about 60% of national exports and employing 40% of the nation’s industrial labor force [18]. The total energy consumption of the textile sector in Pakistan is undocumented owing to the almost complete dependance on captive generation which is off the grid.

The textile sector value chain in Pakistan consists of ginning, spinning, fabric, dyeing and finishing into all forms of textile products. Two of the largest buyers of Pakistan’s textile products are USA and EU [19]. Textile is also an important sector because the industry is not restricted to a certain geographic region like the surgical and sports goods industries in Sialkot. Therefore, an analysis of the energy needs, and grid supply would naturally spread across multiple DISCOs.

Creating the data: Survey Methodology

To elicit the data from the industry, we conducted an energy survey focused on the textile sector through the members of Net-Zero Pakistan coalition. The textile companies that are signatory to the NZP coalition represent one-third of Pakistan’s textile exporters. The survey ran for three months from 17th January 2022 to March 17th 2022 on Duke University’s Qualtrics
platform. The survey questionnaire, as shown in the Appendix focuses on gathering data from the industries across three main topics: their energy demand and grid usage, captive power generation details and details of solar-PV in their captive generation, if any.

The responses we got ranged from 12 large textile exporting companies. The geographical distribution of the survey responses is plotted in the map in Figure-4:

![Figure 4 - Geographic distribution of the survey responses plotted in a map of Pakistan. The geographic divisions show the jurisdictions of different DISCOs.](image)

The survey responses came uniformly from three industrial regions of Pakistan: about 45% came from northern Punjab region (served by Lahore and Gujranwala Electric Supply Company), 25% came from central Punjab (served by Multan Electric Power Company) and 33% came from Karachi (served by K-Electric). This also shows how geographically spread-out Pakistan’s textile sector is.

**Interview sessions with energy management**

The data collected from the survey was complemented by conducting detailed interview sessions with energy management teams from five textile companies that had already responded to the survey. Requests for the interview sessions were sent out to Net-Zero Pakistan signatory companies and the ones that volunteered were interviewed. These interviews consisted of a set of comparable questions that assessed in a greater detail the companies energy needs, perceptions about the grid and its reliability, reasons for using captive power generation, long
term energy security plans and investments, perceptions regarding renewable energy uptake and sustainability measures. The final insights compiled in the following section were a result of synthesis of the survey and interview data.

Outcomes and Analysis

1: Captive generation is used more than the grid

Three quarters of the responding companies had an annual peak electricity demand of more than 10 MW, and no company had a demand below 1 MW. This shows that Net-Zero Pakistan (NZP) signatory companies have large scale manufacturing operations. The vast majority of the companies (83%) had both the grid and captive generation available as power sources. The remaining seventeen percent (17%) only had captive power generation as power source while no company relied solely on the grid. Of the 83% that had both grid and captive power as sources, the majority’s (38%) power came from captive generation while a quarter (25%) of the companies sourced all their power from captive generation. This shows that even with the availability of grid power, most companies relied more on captive generation to meet their energy needs and grid reliance is low.
Natural gas prices and the grid’s unreliability make it less feasible

Natural gas is the most widely used (61%) fuel for captive power generation by the surveyed companies. Most companies have multiple generators for different fuel types. For instance, a factory’s captive power plant could have generators that run on natural gas, coal, and heavy furnace oil. Because fuel prices have been volatile in the past, energy management teams would decide the captive generation fuel mix depending on the fuel price situation on that day. The volatility has now somewhat been reduced by the government by providing a subsidized flat rate of 9 $/MMBtu to export manufacturing companies. This explains why natural gas is so prevalent now in the industrial captive fuel mix. It is important to note here that the government also provides a flat rate of 9 US cents per kWh for grid electricity to these exporting companies.

While the lower price for captive power generation stands out as a reason for companies not using the grid, the grid’s unreliability comes out to be a bigger reason. During the energy interview sessions, all companies stated grid unreliability to be the major reason for not relying on the grid. Even though power cuts have recently been reduced with surplus capacity on the grid – as also shown by Figure 3 – the energy teams complained about fluctuations in frequencies and voltage, and frequent power surges. These surges and fluctuations put some of the critical textile manufacturing operations such as dyeing, bleaching and wet processing at risk of disruption which result in production losses and massive monetary losses. Grid unreliability increases in the summer when loads peak. The only company which expressed trust in the grid came from the Karachi Export Processing Zone (KEPZ) where it was claimed that the grid is reliable for industrial loads and has been upgraded recently. For the textile manufacturing value chain, processes in the lower value chain such as spinning, and weaving are not as
susceptible to grid outages and fluctuations as processes in the higher value chain of denim and garment manufacturing and finishing etc.

While a lower grid tariff would be the largest motivation for companies to switch to the grid, its reliability both in terms of uninterrupted power supply and the smoothness of power supply were close contenders. This shows that companies do not use the grid for their energy needs because the subsidized natural gas for captive generation and the grid’s unreliability make it unfeasible for smooth manufacturing operations.

3: Solar PV is cheaper than both the grid and natural gas

From the data collected through interviews with the energy management teams of multiple companies that had already responded to the survey, we were able to plot the ranges of captive generation prices for different fuels that are available to the industry. These ranges are shown in Figure 9.

![Figure 8: What would motivate you to switch completely to the grid?](image)

- Lower grid tariff: 93%
- Uninterrupted power supply (no load-shedding): 71%
- Reliable power supply (no fluctuations): 79%

![Figure 9: Range of Captive Generation Price by Fuel (US c/kWh)](image)

**Figure 9 - Range of costs incurred to companies at which power is generation from available fuels (@1 USD = 178 PKR)**
The ranges of generation prices emerge because of the different generation technologies used by different companies for captive generation with varying generator efficiencies and heat recovery systems etc. The most important takeaway from the plot is that Solar-PV in captive power generation is cheaper than both the grid and natural gas, even with their subsidized flat rates. The lower end of the Solar-PV range at 1.40 US cents/kWh is representative of EPC projects while the higher end at 6.04 US cents per kWh is representative of electricity contracted on a power purchase agreement (PPA).

Biomass comes out to be one of the lowest fuels for captive generation. This is not surprising because Pakistan’s is primarily an agrarian economy with immense agricultural potential. Even then, only 13% of the captive power generation in our surveyed companies come from biomass (Figure-xx). There are multiple reasons for this: 1) Cost intensive modifications are required in existing generation assets to run them on biomass, 2) The seasonal availability of biomass adds uncertainty to fuel availability and 3) There is a lack of a formal and commercial supply chain for biomass that links consumers with generators.

4: Captive Solar-PV is on the rise

The majority of companies – 80% – had already added Solar-PV in their captive generation mix. This is in line with the cheaper electricity rates from Solar-PV as compared to both the grid and natural gas as shown in the earlier section. This shows that the energy transition to renewables in the industrial captive generation is well underway and there is a successful market running for C&I Solar-PV in Pakistan.

Of the companies that had Solar-PV in their captive mixes, the majority (88%) had a system greater than 1 MW. It is important to note here that for captive Solar-PV, the system size is constrained by the existing rooftop or land space available on the manufacturing site. Our interviews with energy management teams revealed that companies are rapidly expanding their Solar-PV system capacities after successful piloting of smaller projects in the last couple of years. Some textile companies have also used the excess land available to them when faced with a shortage or lack of suitable rooftop space for Solar-PV. Most companies procure their Solar-PV systems through an Engineering Procurement and Construction (EPC)
model. Power Purchase Agreements (PPAs) are rare because of higher electricity rates, a lack of legal expertise and because the process requires obtaining a generation license from NEPRA.

5: State Bank’s RE-refinancing scheme is a success

Half of the companies that had acquired a Solar-PV system in their captive generation mix had used the State Bank of Pakistan’s RE-refinance scheme. Companies were able to secure loans on rates as low as 2% for their Solar-PV projects and these results show that this scheme has been instrumental in driving this rapid growth of Solar-PV in the captive generation mixes of these textile companies.

6: Drivers of rapid solar-PV adoption

The results show that cheaper electricity rates from Solar-PV is the biggest driver of Solar-PV adoption in the industrial captive generation mix. This is despite the subsidy on the two alternates available to these companies: grid electricity and natural gas for captive generation. The next big drivers include sustainability measures, marketing, and compliance with buyers’ requirements. The importance given to sustainability and decarbonization in vary significantly with the company leadership’s vision and goals but net-zero goals across global supply chains in the EU and U.S.A, are significant drivers of this transition. Management teams from all companies expressed the need to comply with the requirements of their buyers in the EU and USA otherwise they faced the risk of losing their share in these markets. Adding Solar-PV in their captive generation mix is one of the ways they can reduce their carbon emissions.
Case Study 1: Quantifying economic benefits of Solar-PV in captive power mix

The results and analysis above make it abundantly clear that the low cost of Solar-PV as compared to the grid and captive power generation from natural gas is the biggest factor driving the transition to renewable energy in the textile industry. The next logical step in this inquiry is to quantify the economic benefit that this low-cost Solar-PV in captive energy mix provides to a manufacturing company in Pakistan. To calculate this, we modeled the energy profile of Company X that was surveyed and interviewed. We calculate the Net-Present Value and Internal Rate of Return that Company X obtained on an investment in adding a Solar-PV system with nameplate capacity of 5.1 MW in its energy mix to offset natural gas generation.

Assumptions:
We used the following assumptions for this analysis:

- Interest rate: 6%
- LCOE of Solar-PV: 3.72 ¢/kWh
- COE of Natural Gas: 10.36 ¢/kWh
- Lifetime: 25 years
- Nameplate Capacity: 5.1 MW
- 100% equity financing

The cost of electricity from natural gas (10.36 ¢/kWh) and the LCOE of Solar-PV (3.72 ¢/kWh) are the average values from Figure 9.

Results:
Company X gets a payback period of just 4 years for this investment in Solar-PV addition in its captive generation mix. The NPV of the project is $12.3 million at the current interest rate of 12.7% [20] and the IRR is 22%. The high IRR shows how lucrative this project is which shows the potential for rapid growth for Solar-PV in the industrial captive generation mix. It is also important to note here the results from this case study lie on the...
conservative end of the spectrum because: the interest rate of 6% is the maximum that is allowed by SBP [14], and developers get rates as low as 2% in reality; LCOE for Solar-PV EPC projects are as low as 1.6 ¢/kWh (as shown in Figure 9); the cost of natural gas is subsidized, and actual costs are higher.

**Impact of General Sales Tax**

The Government of Pakistan implemented a General Sales Tax (GST) of 17% on Solar-PV equipment imports in January of 2022 [21] that were previously exempt from these taxes. To calculate the impact of this tax, we calculated the new NPV, IRR and payback period. For simplicity, we assume that the sales tax will increase the entire LCOE by 17%. This is highly conservative because the sales tax will only increase the cost of equipment and not the project development. The results indicate that the IRR reduces to 16% from 22% and the payback period extends from 4 years to 5 years as shown in Figure-14. These results indicate that the newly implemented sales tax will not significantly impact medium to large industrial captive Solar-PV projects.

![Figure 14 - Revenue cashflow for Captive PV project with and without a GST of 17%](image-url)
Lessons and Recommendations

Evaluation of Natural Gas Subsidy

Our results indicate that the subsidy on natural gas makes the electricity grid uneconomic for industries. The grid continues to remain underserved, and the government continues to pay for the idle generation capacity at a loss to the public taxpayer money. This has significant implications for the circular debt that Pakistan continues to be embroiled in. We recommend an evaluation of these dual costs to the public exchequer in the form of idle capacity payments on the grid and natural gas subsidy for captive generation that are in direct conflict with each other.

Upgradation of T&D Infrastructure

Another major reason for the underserved generation capacity is the grid’s unreliability. The grid has been unreliable for the past two decades and industries have evolved to meet their own energy needs through captive generation. Even though capacity on the grid is now surplus, manufacturing facilities face grid outages during peak summer load times, fluctuations in voltages and power surges that disrupt operations and damage expensive equipment. It is in the interest of both the grid operator and industries to have a reliable electricity grid. For the industries, this would translate in redirecting a large number of human resources to adding value to the manufacturing process instead of ensuring energy security. For the grid operator, the idle capacity on the grid can be served to generate revenue. For these reasons, we recommend that the distribution companies (DISCOs) invest in the distribution infrastructure upgradation to make it reliable to meet the industry’s electricity needs. Using the grid is also doubly beneficial to the industries because the grid emission factor is bound to be lower than their own captive emission factor because the grid takes a quarter of its capacity from hydropower sources with zero emissions. The hydropower capacity in Pakistan’s national grid is going to increase in the coming years as more mega dams come online.

Documenting the captive generation capacity

There is a need to document the captive generation assets and their capacities in all of Pakistan’s industries. To date, there has not been any database or census that documents this. Some estimates put the industrial captive generation to be 22.5% of the total industrial power consumption from the national grid barring K-Electric. This generation capacity has important implications for Pakistan’s true power generation and consumption [6], total emissions reporting from the industrial sectors and most importantly, for grid planning purposes. To date, all of the
planning and forecasting undertaken by electricity sector operators and regulators such as NEPRA and NTDC do not account for this industrial captive generation capacity. This becomes even more important with the increasing share of renewable energy in captive capacity. To serve the idle generation capacity on the grid, the government is encouraging grid use and disincentivizing captive generation by limiting natural gas supply for captive generation [6]. If the grid is to supply power to these industries in the future, the operator has to account for the share of captive renewable energy generation in its demand forecast and dispatch models. To date, this has not been done. We strongly recommend that measures be taken to document the industrial captive generation capacity both for fossil fuels and renewable energy generation.

For the fossil fuel generators, a good starting point to document the captive generation assets would be the customs import data from the Federal Board of Revenue of Pakistan. By extracting the data for all generation assets imported across the border in the last two decades or more, a census survey can be conducted targeted at the industries that are in possession of these generation assets. Information like generation status and efficiencies can be collected.

The documentation of industrial Solar-PV generation capacity would be more challenging. This is because the Solar-PV developer industry is growing fast with numerous developers entering the market. Solar-PV equipment is imported on a bulk level through these developers and then installed in domestic, agricultural, commercial, and industrial projects alike. To trace the supply chain beyond border imports data is difficult because it is not documented. Some of the ways this capacity can be approximated is by using GIS analysis in industrial zones to detect Solar-PV systems and document it in a database. This is complex and has not been done in Pakistan’s context before. Another starting point to document the industrial RE captive capacity is by using data from the State Bank of Pakistan’s RE-refinancing Scheme. While this method could be promising, there is no certainty that it would cover the entire industry because companies that did not use the scheme would inevitably be left out of the process.

All of these methods focus on documenting some aspects of generation capacities and leave others out. This is why there is an urgent need to form a comprehensive database at the central level by the Ministry of Energy. Such an initiative can mandate data collection on an annual or bi-annual level and collect comprehensive energy generation data across all industries in Pakistan that are registered with the Securities and Exchange Commission of Pakistan. This database can potentially serve the entire energy sector in terms of long-term planning and forecasting, and documenting the true electricity generation, consumption, and emissions in Pakistan.

**Sustaining industrial captive Solar-PV generation**

For large manufacturing companies that have excess rooftop and land space, investing in a captive Solar-PV project is a lucrative way of reducing emissions while making profit at the same
time. Solar-PV provides electricity at a cheaper price than the grid and captive generation from fossil fuels. Captive Solar-PV projects are seeing a rapid growth in the textile industry and these results can be generalized for all exporting industries in Pakistan as they face the same grid and natural gas prices. The commercial and industrial Solar-PV developing industry is also growing rapidly as demand for these projects increases. Our results also indicate that the recently implemented GST of 17% on RE equipment imports is unlikely to have significant negative impacts on the uptake of captive Solar-PV in industries.

**Wheeling Regulations**

One constraint in adding captive Solar-PV for industries is the limitations on rooftop and land space on manufacturing sites. As they face mounting pressure to decarbonize their operations faster, the export manufacturing sector in Pakistan is looking towards other ways to reduce or offset their emissions. One promising strategy to achieve this is by Wheeling agreements. Wheeling agreements allow users to use the grid to transport electricity from the point of generation to the load. While NEPRA passed Wheeling regulations in 2015 [22], the instrument has not taken up yet in the sector because the inter-DISCO wheeling regulations have not been formulated yet. It is anticipated that the unbundling of the single buyer model that currently exists in Pakistan into a wholesale competitive power market in the near future will make way for wheeling agreements.

**Continuing State Bank’s RE-refinance scheme**

Our results show that the SBP’s RE-refinance scheme has been a tremendous success in enhancing the growth of RE in industrial captive generation. Half of the surveyed companies that had Solar-PV systems in their captive generation had acquired it through this scheme. The scheme is set to expire in June 2022 and there is uncertainty in the market surrounding it. We recommend that this scheme be continued beyond its current term.

**Renewable Energy Credits (RECs)**

The growing interest to decarbonize and offset emissions in the industries can lead to the formulation of market-based instruments like Renewable Energy Credits (RECs). A Renewable Energy Credit is a convenient way for consumers to offset their emissions from energy consumption by paying for renewable energy production elsewhere. This is especially useful for companies that do not have enough rooftop or land space to install Solar-PV for captive generation or for other reasons. Multiple industries and companies can pool investments to
develop utility scale Solar-PV projects to offset their own emissions. This can assist Pakistan meet its national emission reduction goals as well.

Potential for Biomass

Figure 9 shows that biomass is one of the cheapest fuels available for captive generation to the industries. Some companies that we interviewed showed their plans for producing captive power by using coal-biomass cogeneration technologies. However, biomass is not used as extensively for power generation even though Pakistan has immense potential for biomass owing to its large agricultural output [23]. Biomass produces clean energy in that it does not add any additional emissions into the atmosphere [24].

The potential viability for biomass to be used as a power generation fuel needs to be looked into. Currently, there does not exist any formal supply chain that connects industries with agricultural wase producers directly. The companies planning to use biomass-coal cogeneration are making their own plans to set up their own informal supply chain in Punjab. We recommend that the case for a market-based supply chain for biomass that connects industries and farmers directly be looked into. Depending on how viable this is, this prospect has the potential to provide environmental benefits by reducing stubble burning and the ensuing smog across Pakistan during the winter periods.

Net-Zero Targets are Effective

One of the most important lessons from this study points to the effectiveness of net-zero emission targets across local and global supply chains. Because of initiatives like Net-Zero Pakistan, RE100 and Net-Zero Europe, textile manufacturers in Pakistan are investing in reducing their carbon emissions. All the companies that we interviewed were unanimous in expressing the need to comply with their clients in countries and regions like the United States of America and the European Union. This is not surprising as the US and EU are the biggest two export markets for Pakistan’s textile products [19].
Discussion and Limitations

In this section we discuss the limitations and shortcomings in this project. To begin with, our sample of textile companies consisted of large manufacturers that export all of their produce. More than three-quarters (75%) had an annual peak electricity demand greater than 10 MW which indicates the large scale of their operations. Secondly, the companies we had access to for the survey and interviews had already signed up for Net-Zero Pakistan coalition. This means that these companies already had progressive sustainability goals in place. This adds significant bias to our sample: our sample consisted of large textile manufacturers that export to international supply chains and have carbon emission reduction goals in place. Even though our results are highly insightful for the energy challenges that industries in Pakistan face concerning the grid and ensuring energy security, they cannot be generalized across all industries and sectors.

These results are not representative of manufacturing companies that are small and medium in their scale, do not export, and either do not face pressure to comply with the sustainability standards in international supply chains or do not have progressive and sustainability-oriented leadership. However, we believe that our results can be generalized for similar scale manufacturing companies in other sectors such as cement, dairy, leather, surgical instruments, and sports goods that make up the exports in Pakistan’s economy.
Conclusion

Pakistan’s electricity sector woes have moved from the problems of a demand deficit grid to an underutilized grid. Industrial captive generation is a grey area that represents a large chunk of electricity generation and consumption that is off the grid. Our study shows that the grid continues to remain unreliable and pushes industries to remain dependent on their own captive power generation. Another major reason for the underutilization of the grid is the subsidy on natural gas for captive generation to export manufacturing sectors which makes the grid uneconomic. Our study also shows that captive Solar-PV uptake is also on the rise in large textile manufacturing companies. Electricity rates from Solar-PV are cheaper than the grid and the cheapest captive generation fuel i.e., natural gas which is the major driving force behind this transition. Other driving factors for this shift include compliance pressure from buyers in international markets and sustainability measures from industrial leadership. The capacities of captive solar-PV projects in industries are limited by the availability of rooftop and land space for these systems. This increasing off-grid captive renewable energy capacity in captive industrial generation can have important implications for grid planning, forecasting and national emissions reporting. For these reasons, we recommend that captive generation in industries be documented while sustaining the transition to renewable energy to reduce industrial emissions. It is also proposed that the government evaluate the subsidy on natural gas against the capacity payments for idle generation capacity on the grid that remains unserved and causes economic losses. Such an evaluation should measure the costs of investment in upgradation of the transmission and distribution infrastructure versus the benefits of grid utilization and elimination of subsidy on natural gas for captive generation.
Appendix

Survey questionnaire sent to the industry

Q1 Organization Name (Optional)

---------------------------------------------

Q2 Sector

☐ Textile (1)

☐ Automobile (2)

☐ Cement (3)

☐ Surgical Instruments (4)

☐ Sports Goods (5)

---------------------------------------------

Q3 How long has your company been in operation?

☐ Less than 5 years (1)

☐ 5-10 years (2)

☐ 10-20 years (3)

☐ More than 20 years (4)

---------------------------------------------
Q4 Electricity Distribution Company territory your facility is located in:

- LESCO (Lahore Electric Supply Company) (1)
- IESCO (Islamabad Electric Supply Company) (2)
- GESCO (Gujranwala Electric Supply Company) (3)
- MEPCO (Multan Electric Supply Company) (4)
- FESCO (Faisalabad Electric Supply Company) (5)
- HESCO (Hyderabad Electric Supply Company) (6)
- PESCO (Peshawar Electric Supply Company) (7)
- QESCO (Quetta Electric Supply Company) (8)
- SEPCO (Sukkur Electric Power Company) (9)
- TESCO (Tribal Areas Electric Supply Company) (10)
- K-Electric (11)

Q5 What does your electricity source mix look like?

- Grid (1)
- On-site generation (2)
- Both grid and on-site generation (3)
Q6 What is your peak annual electricity demand? (Please choose the nearest range)

- 10 kW or less (1)
- 10 kW -- 100 kW (2)
- 100 kW -- 500 kW (3)
- 500 kW -- 1 MW (4)
- 1 MW -- 10 MW (5)
- More than 10 MW (6)

Display This Question:
If What does your electricity source mix look like? = On-site generation
Or What does your electricity source mix look like? = Both grid and on-site generation

Q7 What fuel do you use for on-site generation? (Select all that apply)

- RLNG (1)
- Natural Gas (2)
- Coal (3)
- Diesel (backup only) (4)
- Diesel (5)
- HFO/LFO (6)
- Other: __________________________________________

Other: __________________________________________
Q11 What is your ratio of grid to on-site generation?

- Less than 25% on-site generation (1)
- Less than 50% on-site generation (2)
- Less than 75% on-site generation (3)
- More than 75% on-site generation (4)
- 100% on-site generation (no grid electricity used) (5)

Q8 Do you have a rooftop/ground solar PV system on your factory space?

- No (1)
- Yes (2)
Q9 Reasons for using on-site generation (Select all that apply):

- Grid unreliability (1)
- Grid prices higher than on-site generation (2)
- Both of the above reasons (3)
- Other reason (please explain): 

Q10 What would motivate you to switch completely to the grid? (Select all that apply)

- Reliable power supply (1)
- Uninterrupted power supply (2)
- Lower grid tariff (3)
- Other (please explain): 

If What does your electricity source mix look like? != Grid

If Do you have a rooftop/ground solar PV system on your factory space? = No
Q12 What are your barriers to adding solar PV? (Select all that apply)

☐ Lack of rooftop or land space (1)
☐ High solar PV tariffs as compared to grid or on-site gen (2)
☐ High capital costs and lack of financing for a solar PV system (3)
☐ Combined Heat and Power (CHP) is more suited for your process (4)
☐ Other (Please Specify): (5) _________________________

Display This Question:

If Do you have a rooftop/ground solar PV system on your factory space? = No

Q13 What would motivate you to adopt renewable energy technology? (Select all that apply)

☐ Lower solar PV tariffs (1)
☐ Access to financing and lower capital costs for solar PV (2)
☐ Option to sell electricity to the grid (Net-Metering) (3)
☐ Higher fuel price for on-site generation (4)
☐ Compliance with buyer’s sustainability requirements (5)
☐ Marketing for sustainability and green production (6)
☐ Other (Please specify if possible): (7)

________________________________________________
Q14 What is the capacity of your solar PV system?

- 10 kW or less (1)
- 100 kW or less (2)
- 500 kW or less (3)
- 1 MW or less (4)
- More than 1 MW (5)

Q15 What was your motivation for installing solar PV? (Select all that apply)

- Lower electricity prices (1)
- Sustainability measures (2)
- Marketing purposes (3)
- Net-Zero Carbon commitments (4)
- Compliance with buyer requirements (5)
- Other (Please specify if possible): (6)
Q16 How was your Solar PV project procured?

- Equity (1)
- Project Finance (2)
- State Bank's RE refinance scheme (3)
- Power Purchase Agreement (PPA) (4)
- Other (Please specify if possible): ______________________________

Q17 Do you benefit from Net-Metering?

- No (1)
- Option not available by the DISCO yet (2)
- Yes (3)
Bibliography


[16] Z. T. Ebrahim, "Does LNG hold the key to Pakistan's energy woes?," DAWN, 2022.


