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Decision-Making under Uncertainty: Bridging data gaps for effective energy planning

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Abstract

Owing to the absence of research collaboration between government and academia, electricity demand forecasting in Pakistan has long inculcated forecasting errors due to data inconsistencies and modeling approaches. Such forecast discrepancies even within defined error margins can amount to a multifold of a whole sector-level energy demand. Since point forecasts, as being currently practiced, provide a single forecasted value without predefined error margins, forecasters must conduct probabilistic forecasts instead of attaining reliable confidence intervals. In case of faulty forecasts, every extra unit produced bears an economic cost. This factor must be addressed while designing energy policies to avoid unnecessary financial burdening of country's economy. Effective energy policy making can be conceived by developing a coalition between government and academia for collaborative research. To assist such coalitions further, a centralized and publicly available data base needs to be developed for a consistent data input for Pakistan's electricity forecast models. Moreover, the Government of Pakistan must assist synergizing with international donors and agencies to accelerate collaborative research efforts.

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1. Introduction

Today electricity demand is rapidly growing than ever before. Surprisingly, its growth trends among developed and developing countries are highly disproportionate. In some developed economies, electricity consumption per capita is expected to rise to more than 13,000 kWh in the year 2040 Whereas in some developing economies such as Russia and China, the same will reach up to 8000 kWh. Overall, it is expected that by the same year, developing countries altogether will constitute almost 90% of the global electricity demand (International Energy Agency 2019). Similarly, electricity demand in Pakistan is also expected to grow in coming decades (Mir et al. 2020). This growing demand along with the advent of newer technologies in energy and power infrastructure makes it complicated to forecast future electricity demand for a developing country like Pakistan. Clearly, reliability of these forecasts drives through the heart of policy making processes pertaining to asset management, capacity expansion planning, resource allocation, etc. Since forecasting does not aim at 'predicting' future electricity demand with 100% accuracy, it is desirous to do so by formulating different demand scenarios. However, serious ramifications of over/under forecast loads can still result in the mismanagement of already limited resources (Hong and Fan 2016).

A popular practice in literature on forecasting future energy demand is known as *scenario-based forecasting*. For example, in their annual World Energy Outlook (WEO) report, International Energy Agency (IEA) uses the same approach to forecast scenario based future energy demands. While creating two different scenarios as Stated Policies Scenario and Sustainable Development Scenario, IEA provides its future projections for the year 2040 and 2050 for both the developed and developing nations. The primary function of scenario-based forecasting is to analyze the outlook, which will occur by following certain set of policies under a particular scenario. And in the presence of data gaps, as in the case of Pakistan, policy makers frequently tend to reach at wrong conclusions following wrong roadmaps.

The underlying dilemma of the forecasts produced by either government institutions or by academics is that they seldom share any common grounds on metrics of reliability[1]. There are multiple reasons behind that. These include, but are not limited to, nature of electricity demand driving variables, data inputs from varying data sources, data access, different forecasting methodologies, etc. Under these conditions, it becomes inconvenient for researchers to disseminate information based on their individual analyses. In the absence of any benchmark models to base their decisions on, the situation becomes even grimmer for policymakers as well while devising future energy policies based on such forecasts.

Every year, the Government of Pakistan provides future demand forecasts with insights into country's electricity demand sector, as a whole, and elemental contributions of different consumption sectors towards Pakistan's aggregated electricity demand as well. More importantly, these demand forecasts also play a significant role in planning of power system expansion and resource distribution. Therefore, owing to their crucial importance, policy makers in Pakistan partly rely on these forecasts to devise future energy policies for the country.

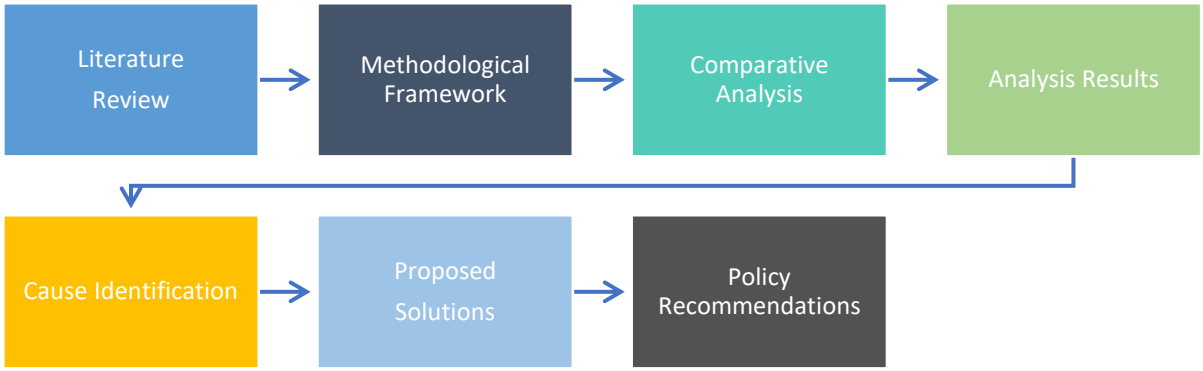
Utilizing demand forecasts and the supplementary data provided by the government, many researchers from academia in Pakistan have long been forecasting electricity demand as well. However, these forecasts rarely come in compliance with the forecasts produced by the government bodies; or otherwise. This is primarily due to the lack of research collaboration between the two. Unfortunately, these researches have been in practice for over two decades,

[1] In Pakistan, National Transmission and Dispatch Company Ltd. (NTDCL), a government institution, is responsible for forecasting country's medium to long term electricity demand.

but the communication gap between government forecasters (for example NTDCL) and academia has since been widening. Inevitably, resulting discrepancies in the forecasts turn into a situation which, to its least, bifurcates the energy policy and decision-making process further towards unreliability and uncertainty.

2. Scope and Objectives

The primary objective of the study is to highlight the absence of research collaboration and communication between government and academia in Pakistan over the problem of accurate electricity demand forecasting. To achieve this, the study analyzes numerous notable works from literature on demand forecasting in Pakistan in comparison to the forecasts provided by government bodies. This comparative analysis aims at extracting the reasons behind the discrepancies in the forecast figures provided by both the stakeholders. Based on the post analysis findings, solutions to bridge these gaps between the stakeholders are proposed to avert unreliable forecasting practices in future. The scope of the study also extends to suggesting policy-based measures to overcome the dearth of collaborative research and lack of communication between the said stakeholders. Prospects of involving international donors like UN, World Bank, USAID, UKAID, etc. to the solution process are also presented. In a nutshell, scope and objectives of this study are graphically illustrated in a framework in figure below.



3. Literature Review

Research on electricity load forecasting has been continuing for the past two decades (Mir et al., 2020). Unfortunately, these research trends are not very similar in Pakistan. Although there have been numerous studies that addressed the problem of demand forecasting in Pakistan, the inconsistency in forecasting research trends has remained the unwanted side of the same coin. Mostly, researchers from academia focus on forecasting for medium and long-terms (Hussain et al. 2016; Perwez et al. 2015; Perwez and Sohail 2014; Ur Rehman et al. 2017). This is primarily due to the fact that data for long-term forecast models is readily available through a variety of different data sources such as Pakistan Economic Surveys, Hydrocarbon Development Institute of Pakistan, Alternative Energy Development Board, World Bank, UN agencies, Asian Development Bank, etc. However, scarcity in short-term load forecasting owes its existence to unavailability of required data like load and weather data from distribution companies and Pakistan Meteorological Department respectively.

Since the year 2000, researchers from government bodies and academia have published numerous works on short, medium and long-term load forecasting. For example, in (Perwez et al., 2015), authors suggested a scenario to be cost-effective and environmentally viable for Pakistan's future demand in 2030. Authors also suggested a demand growth of 177% in 2030 compared to the base year 2011. In another study, researchers from government bodies presented a methodological framework claiming that their models results were in close approximation to actual demand figures in the past (Saleem et al. 2017). Similarly, different authors used different forecasting approaches as reliable means of forecasting future electricity demand for Pakistan (Burillo et al. 2019; Gul et al. 2011; Khan et al. 2020).

4. Data and Methods

Besides the government's annual demand forecast reports, only the academic literature sharing common forecast years with the government's forecasts were considered and explored for the analysis. Comparison metrics were defined for data pertaining to forecasting methodologies, techniques, data resources, and demand determinants used in these studies. These data indicators were then compared with the ones used by the government bodies and factors behind forecast discrepancies were extracted. A glimpse of one of these indicators is shown in Table 1 for the electricity demand determinants used by academia and government bodies in Pakistan.

Table 1: Model determinants for electricity demand forecasting in Pakistan (National Transmission and Dispatch Company 2019)

ACADEMIA	GDP, GDP growth rates population, population growth rates, population growth control plan, energy intensity, forecasted growth, income per capita, seasonal variations, industrialization, rate of urbanization, penetration of energy efficient devices, fuel cost, technology's lifetime, plant capacity factor, number of households, household size	NTDCL	GDP, GDP elasticity, population, consumer price index, electricity prices, price elasticities, number of consumers, transmission and distribution losses, energy not served (load-shedding), lagged variables and their elasticities

Following the development of the study framework, forecasted demand for the year 2020-2021 from a government institution was set as a benchmark. This benchmark was then used for comparison with the forecasted demand figures for the same year from academia in Pakistan. In this comparison, lower and upper bounds of the government's demand projections were set with ±5% and ±10% margins. It is important to note that there is no significance attached to selection of the year 2020-2021 apart from highlighting the fact that a mere comparison of one year forecasts can reveal striking dissimilarities, let alone the compounded error on the forecasts for decades ahead.

5. Results and Analysis

In 2019, in a government release, electrical energy demand forecasts of Pakistan for the year 2020-2021 were presented (National Transmission and Dispatch Company 2019). Energy demand for the same year was also independently forecasted by many researchers in academia as well. Both these sets of demand forecasts, when compared, provided startling insights. This comparison was made by establishing two error margins of ±5% and ±10%. While comparing demand forecasts from some notable academic researches with the government forecasts, it was revealed that there lies a huge gap between the forecasted figures. This is summarized in Table 2.

Table 2. Summary of electricity demand forecast studies in comparison with government forecasts

Energy (TWh) demand projection in contrast to NTDC's base forecast (TWh purchased by CPPA) for year 2020-2021 (166.2 TWh) **± 5% error bracket: 157.8 TWh – 174.5 TWh** **± 10% error bracket: 149.5 TWh – 182.8 TWh**					
Academic Researches	Forecasted Demand	Forecast Difference	Forecast Status	Error Compliance	Reference
Perwez et al.	180 TWh	+13.8 TWh	Over forecast	Yes	(Perwez et al., 2015)
Hussain et al.	98.5 TWh	-67.7 TWh	Under forecast	No	(Hussain et al., 2016)
Rehman et al.	98.6 TWh	-67.6 TWh	Under forecast	No	(Ur Rehman et al., 2017)
Perwez and Sohail	160 TWh	-6.2 TWh	Under forecast	Yes	(Perwez and Sohail, 2014)

Gul et al.	101.8 TWh	-64.4 TWh	Under forecast	No	(Gul et al. 2011)
Khan et al.	80.0 TWh	-86.2 TWh	Under forecast	No	(Khan et al., 2020)
Ishaque et al.	125 TWh	-41.2 TWh	Under forecast	No	(Ishaque, 2017)
Gul and Qureshi	190 TWh	+23.8 TWh	Over forecast	No	(Gul and Qureshi, 2012)

It is worth noticing that a majority of these studies appear to be under-forecasting the demand. This indicates that when policy makers attempt to rely on such forecasts, resulting policy will further nudge the country into insufficient energy generation and hence increased load-shedding in future. In case of over forecasting, extra energy will likely be produced. This energy, since in surplus, will not have any economic utility to it.

In Figure 2, a comparison between demand forecasts from academia and government with error margins of ±5% is shown. From the perspective of its significance, a five per cent error on 166.2 terra watt-hour (TWh–energy unit) equals 8.3 TWh of electrical energy. Not to mention, this accounts for 140% of Pakistan's commercial electricity demand of year 2015 and 103% of its agricultural electricity demand for the same year (NTDC., 2019). However, and surprisingly enough, forecasts from academic sector of Pakistan barely come in compliance with the forecasts produced by the government bodies. From a study set explored, forecasted demand from only one study appeared to be in proximity with the forecast produced by government. As shown in Figure 2, rest of the 87.5% studies showed extremely deviant forecast results, comparatively.

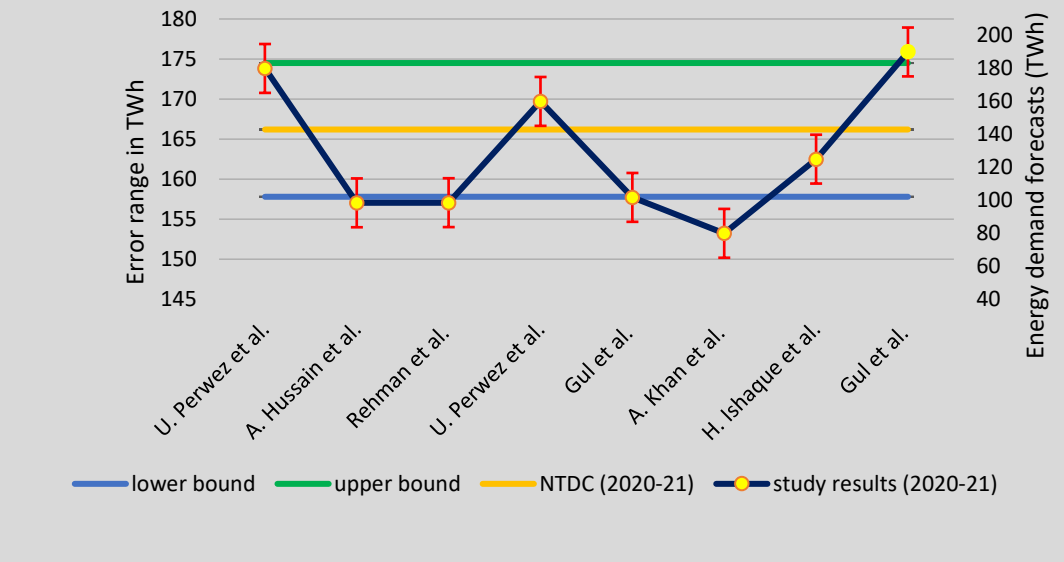


Figure 2. Forecast comparison with error margin ± 5%

Similarly, when error margins were increased from ±5% to ±10%, results from only one more study managed to comply with government's forecast figures. This accounts for the ratio of one-to-four academic studies, in general, complying with forecasts produced by the government. This is illustrated in Figure 3.

Since a 10% error on 166.2 TWh equals to 16.6 TWh, it is interesting to notice that this amount of energy is more than the energy demand of both the commercial and agriculture sectors of Pakistan for the year 2015 and is more than 300% of the energy demand of 'other-sectors' for the same year as well (National Transmission and Dispatch Company 2019).

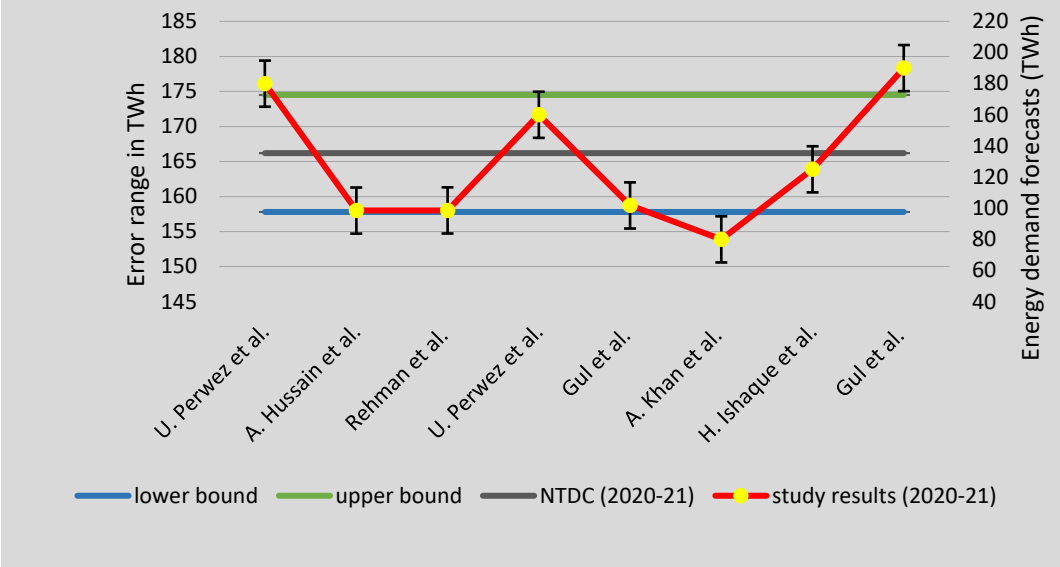


Figure 3. Forecast comparison with error margin ± 10%

Such discrepant forecasts indicate lack of communication, collaborative research, and disproportionate access to data sources between independent academic researchers and government bodies. Absence of industry-academia linkages is another significant reason behind these deviant forecast results. For a precarious situation like this, notable researchers in the field of load forecasting suggested and adopted certain measures in their relevant domains. These adaptations, as evident from their impacts, can certainly be introduced in Pakistan as well. For example, in North Carolina (USA), academic forecasters have developed nexus with the independent system operators (ISOs) in the region. This resulted in a research collaboration where ISOs provided full data access to academic researchers. In return, these forecasters from academia equipped ISOs with state-of-the-art forecasting models–hence a win-win situation (Hong and Fan, 2016). Similarly, Australian Energy Market Operators (AEMO) have publicized their data for independent researchers. For example, (Qiu et al. 2018) have used extensive data from AEMO and proposed an advanced short-term load forecasting model. This model is applicable in real world forecasting applications and hence carries an unquestionable economic utility.

Unfortunately, in Pakistan, no such data is publicly available. This is partly due to the lack of initiatives as well as resources for developing and maintaining rich data resources like AEMO's. To fill the void, the government can consider seeking collaboration with international agencies like UNs, World Bank, USAID, UKAID, etc. These agencies can be instrumental not only in maintaining a publicly available data resource but also bridging communication gaps between policy makers, government stakeholders and academia as well. Capacity building workshops, resource and technology sharing, and software training programmes on short, medium, and long-term load forecasting are one of the viable options available on table. Such activities will potentially provide a conducive environment for both the policy makers and stakeholders to network with each other and advance side by side in developing better communication today for the better policies tomorrow.

6. Conclusion

In the wake of diminishing collaboration between forecasters from academia and government, this issue highlights electricity demand forecasting practices in Pakistan over last two decades. It takes its readers' attention to the major stakeholders on the subject area and dissects their individual as well as collective efforts to extract meaningful insights. Demand forecast from these two stakeholders were compared and it was concluded that forecasts produced by both the major stakeholders are mutually deviant and incur immense discrepancies. It was also established that the discrepant forecasts as these find their root causes back into the type of forecasting methodologies, techniques, data sources, and sets of electricity demand determinants that were used in forecast models. It is worth noticing that some of these indicators were found to be mutually inclusive between both the stakeholders. However, there were many more which were mutually exclusive and must therefore find a common modeling framework to be unanimously incorporated into. In terms of the financial repercussion that these faulty forecasts bear, it can be concluded that forecasting discrepancies (over-forecasting) bear an economic cost, which if not addressed, can become a looming burden on Pakistan's already dwindling economy. In terms of electricity units, every tera watt-hour introduces a unit cost which can have an aggregated economic impact on country in the longer run. These faulty forecasts (under-forecasting) can also push Pakistan into severe load-shedding in future as well. Since both the stakeholders are equally significant in the provision of inputs to the energy policy makers in Pakistan, their mutual research collaboration now becomes indispensable more than ever before.

7. Policy Recommendations

To facilitate such a collaboration, this study suggests that:

- A centralized and publicly available data base needs to be developed for a consistent data input for forecast models.
- Data providers such as Pakistan Bureau of Statistics (PBS), Hydrocarbon Development Institute of Pakistan (HDIP), Alternative Energy Development Board (AEDB), National Transmission and Dispatch Company (NTDC), National Electric Power Regulatory Authority (NEPRA), Private Power Infrastructure Board (PPIB), etc. need to be regularized in their data releases for seeking unanimity.
- Coalition of researchers from government and academia needs to be assured. These research clusters are essential for providing mutually reliable demand forecasts for policy makers.
- Major stakeholders such as NTDCL, NEECA, PEECA, AEDB as well as all relevant research groups from academia must be coerced into a research consortium for producing reliable forecasts.
- Benchmarking of demand forecast models and their parameters needs further nourishment to provide reliable intakes for Pakistan's energy policy making process.
- Financial stimuli should be provided to academia for independently conducting spatial surveys.
- The government must initiate collaboration with the international agencies/donors to develop a centralized data source and keep it open access for researchers.

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