Research in Forecasting Natural Gas reserves and shortage in Pakistan

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Abstract

This study examines the Natural Gas sector Demand and Supply trends over the past 12 years. The study discusses past petroleum policies and schemes introduced by the government and how these policies turned out for the Natural Gas Sector. The natural gas sector is further discussed as the primary energy source for Pakistan which is an economically developing country. The natural gas has a number of sectors that demand for the fuel because of its BTU ratio and high conversion rate to energy. The natural gas sector experienced shortfalls from 2012 onwards. This situation is examined further from 2014 to 2019 to analyze the seasonal changes in demand and supply of Natural Gas in Southern Pakistan. Using the previous data, this study considers seasonality and performs a linear regression analysis on the Natural Gas demand and supply for the next 3 years. The study of linear regression reflected growing shortfalls of approximately 280MMCFD every month for the next 3 years. The study then further examines the significance of each sector that demands natural gas using FUZZY TOPSIS in order to reallocate the sale of natural gas to particular sector in order to optimize its usage and minimize the natural gas forecast to minimal shortfalls. The current natural gas reserves of Pakistan are depleting and are expected to exhaust by 2030 if no new reserves are discovered and the shortfall continues. This study finally concludes that Southern Pakistan is forecasting an average shortfall of 280MMCFD every month which can be reduced by supplying natural gas to Captive power and power generation sectors. Other ways to reduce shortfalls are recommended among which measures to reduce Unaccounted for gas (UFG) are highly weighed in. Current UFG of 18% shall be reduced to approximately 6% to reduce wastage of natural gas. Moreover, the study finds that CNG and Cement Industries shall be diverted to alternative sources of energy since they do not contribute significantly to the economic growth of Pakistan and can be shifted to other sources of energy.

Keywords: Demand, Supply, shortfall, petroleum, energy, Captive Power, Industries

1. Introduction

Natural Gas is a naturally occurring gas mixture, containing hydrocarbons mostly methane with the chemical formula CH3COOH. It normally does not have any smell hence traces of Sulphur are added so that it has some odor and can be detected in case of a leak. Natural gas is a non-renewable energy resource derived from fossil fuels similar to coal and oil, but it has a much higher efficiency in terms of energy content output. And when we talk about Pakistan in specific, Natural gas is one of the most common sources of fuel for various industries and sectors. The major reason why it is used so much is evident from the fact it has extremely efficient BTU (British thermal unit) input to BTU use ratio. (Zuberi, 2006)

In the decade prior to the last one i.e., (2000-2010) the world natural gas scenario completely changed. Natural gas was becoming the primary energy source much due to the fact that it was cleaner than coal & oil and also because of its higher BTU content. The most robust demand was expected to take place in developing countries than developed countries primary South Asia. Natural gas accounted for almost a quarter of world's energy consumption, and it was projected that demand would increase at an average rate of 2.2% per annum till 2020. (Zuberi, 2006) With this advent world's resources of natural gas grew as a result of innovations in explorations and extraction processes. It is estimated that still there are a lot of untapped natural gas reserves in the world.

As predicted the growth of Natural gas was in South Asia that includes India and Pakistan primarily due to high population in this region. And as Pakistan being a developing country it was true and demand for natural gas grew rapidly at a rate of 9.4% per annum. (Zuberi, 2006) Pakistan being an agriculture-based country relied heavily on natural gas as energy source for growth. Natural gas is a major feedstock for fertilizer industry to produce Ammonia, which in turn is very crucial for the farming industry (primary industry of Pakistan). Secondly the import bill of Oil added too much burden on the balance of payments and halted the economic growth of Pakistan. Hence, we shifted to using natural gas to generate electricity from power generation plants.

Since then, the situation has not changed we are still using natural gas in fertilizer industry and power generation and now with increased demand due to population growth. In fact, we have added some other sectors too to exhaust natural gas reserves like using CNG for transport sector, LPG for heating and cooking purposes. And due to these reasons, the demand for natural gas has grown exponentially and is still increasing now more than ever. Currently Pakistan consumes 1,590,904 million cubic feet (MMcf) of natural gas per annumquotedfor the year 2017. (Worldometer, 2017) Additionally we have also got to the point where we also import some portion of Natural gas roughly around 3% of annual demand.

Our dependency on natural gas as an energy resource is evident from the figures quoted above. And things look pretty worrying when we look at our reserves and how fast they are depleting. Pakistan largest source of natural gas is Sui located on the border of Sindh and Balochistan and was discovered in 1952. (Zameen blog, 2020) To this date we have discovered various other reserves. There are currently 26 gas fields – 24 in Sindh and 2 in Balochistan. Despite all of that we are still currently facing gas shortage and have to import gas as we have not discovered new reserves. Our reserves are depleting fast due to the ever-increasing demand and our poor planning of utilization of resources. As quoted by (worldometer, 2017), Pakistan has around 19 trillion cubic feet (Tcf) of gas reserves and our demand is around 16 million cubic feet which means we have reserves approximately equivalent to 12 times our annual consumption. This effectively means that Pakistan has 12 years of gas left at current consumption and not including untapped reserves. (worldometer, 2017)Considering the current population of Pakistan and its growth in recent years we might have just 10 years of natural gas at the current supply level.

The figures quoted above are very alarming and worrying as this halt the economy of Pakistan which is already struggling in recent years. Hence there is an urgent need to plan how we need to utilize our current resources efficiently and also start looking for new reserves of gas to fulfill the demand. This is of the major objectives of this research paper. This research paper will use the previous historical demanddata for natural gas and predict demand for the next 5-10 years for different sectors. Using linear regression model and fitting the regression line to previous demand data, the future demand will be predicted. This will give us a better idea of how our demand would potentially look like in future and how much gas will need to be imported to fulfill the demand. The demand will be predicted individually for each sector like fertilizer, power generation, domestic heating and cooking etc.

By predicting demand for each sector enables us in segmentation and set up priority ranking of these sectors. Then we can apply the TOPSIS approach to effectively identify high priority sectors that need to be supplied with natural gas. The priority will depend on different factors like substitutes available, efficiency, interdependencies towards other sectors, crucial towards growth of primary industry and exports etc. For example, fertilizer industry is very crucial as Pakistan is agriculture-based country and major exports depend on the farming industry. Similarly, the transport sector has other alternatives like diesel, petrol and hence its priority will be low. In this way we can effectively identify the major sectors of natural gas consumption and only supply natural gas to those outlets. For the rest of the sectors, we need to divert them to alternate sources so that we have ample resources for our priority sectors. This will be major aim of the research paper

2. Literature Review

The indigenous supply for Natural Gas has a major share in Pakistan's energy mix standing at 34.6% in 2018. It is complimented by imported LNG that has around 8.7% share in the energy mix. However, the excessive usage of natural gas and slow growth in reserves has led to shortfalls. Therefore, the government introduced policies and strategies to cope up with the shortfall. Government's Petroleum policy 2012 focused on exploration and production of natural gas. It reduced the exploration licenses from 9 to 7 years to accelerate exploration in pursuit of new gas reserves. Moreover, it offered better gas prices to E&P companies aimed to attract more investment. A monetary benefit of US $1/MMBTU is also offered for first three discoveries in offshore areas. Policies like Low BTU Gas Pricing policy were also aimed at achieving fast track development and production of gas from low BTU Gas reservoirs and provided an opportunity for exploration of Low BTU Gas which could increase the power generation capacity. However, Government of Pakistan has somehow failed to reduce shortfalls as consumption keeps on increasing whereas reserves continue to deteriorate.

2.1 Energy Production and Consumption

In FY2018-19 the total primary energy supplied in Pakistan was 86.3 MMTOE. This was a notable growth of 8.4% from the last fiscal year. The share of indigenous natural gas was 34.6% registering as the biggest source of energy. LNG Imports accounted for 5.6% of the energy mix. Oil remained second with 31.2% share. Other major sources include hydro, coal, nuclear, and imported electricity. The consumption of Natural Gas in Pakistan is distributed among different and diverse industries. Primary consumption of the energy was by the private sector (38%), transport sector (22%) and industrial sector (26%). The residential sector accounted for (8%). The fertilizer sector accounted for (5%) of the energy.(Ministry of Energy (Petroleum Division) Government of Pakistan, 2020)

2.2 Natural Gas Production

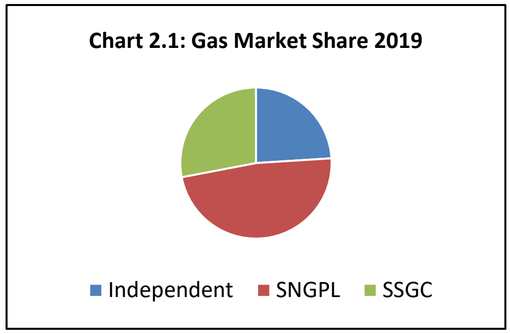

Figure 1: Gas Market Share 2019
GOP/PetroleumDivision.pk

The Natural gas sector includes two partially government owned companies – SSGC and SNGPL that provide gas to the majority of the country, whereas a small volume of gas transmission exists that is owned and operated by gas producers or bulk consumers for direct supplies. Indigenous gas production has increased significantly. An increase of 480% was recorded as production increased from 709MMCFD in 1980 to 4126 MMCFD in 2010. A fair share is contributed by the imported LNG accounting for 48,382MMCF to the total reserves. However, Pakistan is faced with a severe gas shortage which is turning into a notable crisis. This shortage has affected power generation as well as industrial production. The government has executed a number of policies to counter the increasing shortfall. In 2010, Government of Pakistan, implemented a regular load shedding of gas applicable on certain sectors. This included transport industry, where gas was cut off weekly to transport industry thus reducing its usage as vehicle fuel. Natural gas production decreased by 3.4% from 4259 MCFD in 2012 to 4126 MCFD in 2013, whereas its consumption also declined by 1.6% from 3520 MCFD to 3464 MCFD during the same period. (Ministry of Energy (Petroleum Division) Government of Pakistan, 2020)

2.3 Natural Gas Consumption

Pakistan consumes 1,590,904 MMCF of natural gas per year as of the year 2017. Pakistan consumes 7,652 cubic feet of natural gas per capita every year (based on the 2017 population of 207,906,209 people), .The distribution of Natural Gas consumption is dominated by power sector consuming approximately 38% followed by domestic usage of 21%.(Ministry of Energy (Petroleum Division) Government of Pakistan, 2020)

Energy is an essential need for any developing country. A country like Pakistan that is currently growing at a slow pace with uncertainty requires least disruption in their primary energy supply in order to fuel uninterrupted growth and industrialization. However, Pakistan is faced with classic problem of scarcity of resources. Pakistan’s major chunk of primary energy comes from natural gas. The Natural Gas Reserves are declining fast with ever increasing demand for production activities. To summarize, Pakistan has a shortage of Natural gas with the problem of excess demand by multiple industries. This problem requires efficient reallocation of Natural Gas to certain industries according to their importance for Pakistan’s economy as a whole. We will do so by weighing each sector’s importance and allocating Natural gas according. As for the least important sectors which has possible substitutes, we shall aim to reallocate them substitutes to natural gas in order to optimize the usage of scarce natural gas in Pakistan without slowing or interrupting economic growth. This optimization and reallocation are possible by initially determining what the demand will be like in the years to come. For that purpose, a lot of research and methods have been applied to forecast demand of natural gas for different countries. Since, this problem persists in multiple countries, it has to be addressed in the most realistic and efficient way possible. Forecasting is important to assess expenditures, consumptions, and energy management.

Multiple models have been applied in the hope to efficiently predict and forecast the future demands of natural gas in different countries. These models relied on econometrics, time series, neural networks, and other copes of predictive analysis. In Spain, a study was done on natural gas where researchers like (Gutierrez, Nafidi, & Sanchez, 2005)produced a stochastic approached model of natural gas demand in the respective country. Moreover, (Al-Fattah, 2005)used the time series model to predict the production of natural gas in the U.S where he forecasted annual depletion till the year 2025. The time series forecasting uses linear models of Auto-Regressive integrated moving average (ARIMA).(Erdogu, 2010)forecasted growth in demand of Natural Gas using ARIMA Models.

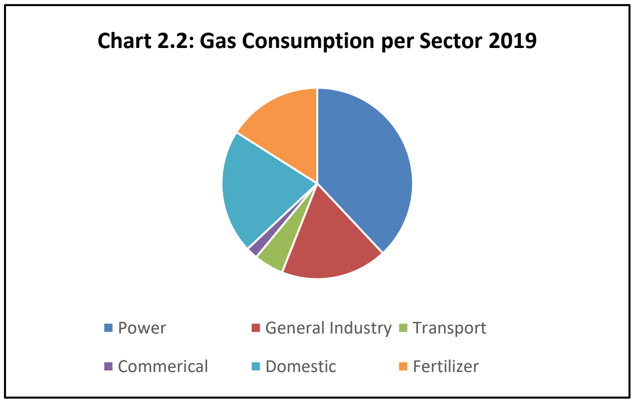

Figure 2: Consumption Sectors of Natural Gas
GOP/PetroleumDivision.pk

Another very frequently used forecasting model is based on Artificial Intelligence.This study included Neural Networks as well as Genetic Algorithms which figured patterns from the past data that was fed to the system. (Kizilaslan & Karlik, 2009).Neural Networks are useful in determining complex relationships between multiple variables in energy forecasting. (Demirel, Zaim, Caliskan, & Ozuyar , 2012) took approach of neural networks and multivariate time series methods to predict Istanbul's natural gas consumption. They may be used without any prior assumption or factors accounted for. Genetic Algorithms (GAs) are used through stochastic approach which enables them to search for optimum parameters.(Forouzanfar, Doustmohammadi, Menhaj, & Hasanzadeh, 2010) used the GAs to forecast natural gas consumption. They differ from econometric models in a way that GAs do not consider economic factors which compromises its precision and accuracy. Hybrid models are also used in research that spread over more than one country. It blends techniques for both linear and nonlinear characteristics. These models use both time series techniques and ARIMA alongside Neural Networks.

A residential natural gas forecast was also done for Croatia (Potonik, et al., 2014)based on comparison of static and adaptive models. Some models focused on each sector that consumed natural gas. For instance, (Khan, 2015)predicted Pakistan's natural gas consumption for each consumer sector like residential, industrial, and Power sector. Italy's natural gas forecast was done by (Scarpa & Bianco, 2017)using regression algorithms. Similarly, Machine Learning models were used to forecast natural gas demand in Ljubljana.(Hribar, Potocnik, Silc, & Papa, 2019) There have been different methods employed to accurately predict natural gas consumption in different countries. One of the more commonly used methods is the Grey Forecasting model derived from Grey Theory. They are divided into univariate models and multivariate models. Univariate models are analyzed on the basis of time series whereas multivariate models are analyzed by dependent and independent variables. When monthly demand predictions are aimed, seasonality becomes one of the variables since gas demand varies with each month of the year. Another significant study is the Market Allocation Model (MARKAL) and Long-range Energy Alternative Planning system (LEAP). The MARKAL approach focuses on the supply side of energy systems. These programming approaches were developed by Energy Technology System Analysis Program (ETSAP) of International Energy Agency. This approach is developed by Lead Cost Linear Programming Model. MARKAL model minimizes the costs borne for the entire energy system and keeps the energy demand as constant. This helps in analyzing different energy systems at regional, state, and national level. (Es, 2020)

The studies conducted prior using multiple approaches have been effective in forecasting natural gas demands. However, it is also important to determine that the demand is directly dependent on the availability and supply in order to fulfill the gas demand. The natural gas shortage can only be addressed if the supply was also forecasted for the future. To do so, this study will forecast both natural gas demand and indigenous gas supply in future in Southern Pakistan. This study will take into consideration the effect of seasonality across the year and analyze the monthly forecasted supplies and demand of natural gas. By doing so, we shall analyze if there will be a shortfall of natural gas in Pakistan to meet the demand. This will be done by assigning seasonal indexes of each month and applying a linear regression model with seasonality to forecast gas demand and supply. To further this study, a research will be conducted to determine the significance of each sector for the economy. A FUZZY TOPSIS approach will be used by conducting a survey taken by employees and individuals working in the Natural Gas Industry and are considered experts in the case of this study. By understanding the responses of these individuals, we will assign each sector the importance of supplying Natural Gas to them. By doing so, we will allocate Natural Gas to the most important sectors and look to optimize its usage and consumption in Pakistan in order to maximize the life of current Natural Gas Reserves in Pakistan that are running out quickly.

3. Methodology

3.1 Data Collection

The data for this study has been acquired by approaching multiple credible and experienced employees in the Petroleum Industry, particularly in the natural Gas Sector. Pakistan's Natural Gas Sector supply is managed by two major companies: Sui Southern Gas Company Ltd. (SSGC) and Sui Northern Gas Pipelines Ltd. (SNGPL). SSGC was approached for monthly statistics of both Natural gas Supply and Demand and quantitative data for each month's demand and supply was acquired for the past 15 years. The monthly figures for each year will be used to predict yearly consumption of Natural Gas in the coming years.

Since we already know the fact that our natural gas reserves are depleting, and we need to supply gas only to priority sectors. Hence next up, we aim to optimize the consumption of Natural Gas in Pakistan by reallocation among different consumer sectors based on the importance of each sector. This optimization will be done by analyzing the opinion of experts in the Natural Gas sector. For this, a questionnaire was designed that was filled out by individuals who have significant experience in the respective industry. We weighed in their opinion based on their designation, the company they are employed in, and the years of experience they have gained. The questionnaire aims to rank 7 sectors that consume Natural gas in Pakistan based on 3 criteria. The criteria include Total Demand from each sector, their total revenue collected and their contribution to country's Economy. They were asked to rate the importance of these sectors with respect to these criteria. Their opinion shall be weighed according to these responses and based on these, a FUZZY TOPSIS model will be designed.

Table B5 in the appendix B shows the details the of the respondents. Most of the respondents have a direct relation to gas supplier companies like SSGC, Gasco Engineering, Nooriabad Power Plant etc. Others include sectors like K-Electric, Fauji Fertilizer so that we get an accurate measure and response from all sectors and reliable people in this sector. Most of the respondents for the survey have ample experience and the average experience of all the respondents is above 21 years. This shows that our survey has a small sample size but has significant credibility as most of the people have ample experience under their belt. Therefore, their answerson the questionnaire are reliable and forms the strong base for our results discussed later in the paper.

3.2 Modelling Techniques

1. Linear Regression:

The demand for Natural Gas in Southern Pakistan is presented quantitatively for each month in our acquired data. The Total Demand figures are assigned as the dependent variable for our predictive model. The respective months of the proceeding years are assigned as the Time Period which is the independent variable X. A linear equation is formulated for the relationship between X and Y using all the available Demand Values for respective months.

X = Time Period

Y = Actual Demand Value

To forecast Demand Data for each monthly period, seasonality has been taken into utmost consideration. The Demand for Gas varies in different months of the year. For instance, during winters, Natural Gas demand increases for heating purposes. Similarly, in summers, demand for electricity increases due to greater consumption by Air Conditioners. Therefore, to evaluate the impact of seasonality on our predictive model, we computed Seasonal Index for each Time Period. We begin by calculating Centered Average. The centered moving average is evaluated for 5 time periods with the required time period centered. The formula below describes Centered Moving Average

$$Centered\ Moving\ Average\ for\ Period\ X_n = \{(0.5 * X_{n-2}) + X_{n-1} + X_n + X_{n+1} + (0.5 * X_{n+2})\}/4 \qquad (1)$$

The seasonal Ratio is then evaluated for the respective Time Period by comparing Actual value (Y) with the centered average evaluated prior. The following equation describes its evaluation.

$$Seasonal\ Ratio = \frac{Actual\ Value}{Centered\ Average} \qquad (2)$$

The seasonal Index is then evaluated for each month is evaluated by averaging the seasonal ratios for each month for all the years.

$$Seasonal\ Index = Average\ of\ Seasonal\ Ratios\ for\ each\ month\ over\ all\ years \qquad (3)$$

We now obtain the Natural Gas Demand values by ignoring the seasonality factor. The equation below computed un-seasonalized values.

$$Unseasonalized\ Value = \frac{Actual\ Value}{Seasonal\ Index} \qquad (4)$$

The regression is performed on these values to build a predictive model to forecast demand for future time periods. To forecast Natural Gas demand for each time period by initially ignoring the factor of seasonality, we evaluate the intercept and slope for the linear regression model for the respective variables.

$$Y = mX + c$$

$$X = Time\ Period, Y = Gas\ Demand, m = slope,\ c = intercept \tag{5}$$

The slope and intercept of this regression model is evaluated for relationship between Un-seasonalized Values and the Time Period.

Finally, to forecast Gas Demands for each time period with seasonality in consideration, we evaluate Seasonalized Values.

$$Seasonalized\ Values = Unseasonalized\ Values\ \times Seasonal\ Index \tag{6}$$

The forecasts of this model may be subject to minor inefficiencies and this study evaluates the error our predictive model. To evaluate the forecast error, we calculate the absolute error by simply subtracting forecast demand from the actual value.

$$Absolute\ Error = Actual\ Demand - Seasonalized\ Forecast\ Demand \tag{7}$$

The model then evaluates the squared error by simply applying the square function. Percentage errors are then evaluated.

$$PercentageError = 100 \times (AbsoluteError)/(ActualValue) \tag{8}$$

2. Fuzzy TOPSIS:

The reason we use Fuzzy TOPSIS(Technique for Order Preference by Similarity to an Ideal Solution) is primarily because it difficult for a decision-maker to assign a precise performance rating to an alternative (in our case each sector) under different criteria. The merit of using a fuzzy approach is used assign the significance of attributes using fuzzy numbers instead of discrete numbers. (Yang & Hung, 2005)

This method is better than normal TOPSIS as this allowsmore flexibility in the decisionboundary as it uses Fuzzy numbers instead of precise discrete numbers. The mathematical models and equations are taken from the research paper from (Kabir & Hasin, 2012). In this case we will be using a triangular Fuzzy number and it can bedefined as (a1,b1,c1). The mathematical equation is shown below:

$$u(x|M) = \begin{cases} 0, & x \le a_1 \\ \frac{x-a1}{b_1-a_1}, & a_1 < x \le b_1 \\ \frac{c_1-x}{b_1-a_1}, & b_1 < x \le c_1 \\ 0, & x > c_1 \end{cases} \tag{9}$$

Definition 1: Let $M_1 = (a_1,\ b_1,\ c_1)$ and $M_2 = (a_2, b_2, c_2)$ are two triangular fuzzy numbers, then to calculate the distance betweenthem given below:

$$d(M1, M2) = [\ 〖1/3\ \{(a1 - a2)^\wedge 2 + (b1 - b2)^\wedge 2 + (c1 - c2)^\wedge 2\ \}]〗\ ^\wedge(1/2) \qquad (10)$$

Property 1:

$$A_1 \otimes A_2 = (a_1, b_1, c_1) \otimes (a_2, b_2, c_2) = (a_1 * a_2\ , b_1 * b_2, c_1 * c_2) \qquad (11)$$

Next up we defined the Fuzzy Triangle values for different attributes that will be assigned by the experts. This is shown below in Table 1:

Table 1: Fuzzy Numbers for Ratings

Term	Fuzzy Number
Very Low	1,1,3
Low	1,3,5
Average	3,5,7
High	5,7,9
Very High	7,7,9

In our case for this project, we have gotten responses from 10 experts from different people in the energy sector especially in the Gas sector. We have 7 attributes or sectors of natural gas consumption, and we will now rank them according to priority and weightage set by the experts. The attributes are shown below, and these will be used for simplicity in future:

Table 2: Consumption Sectors

A1	Electricity Generation
A2	Fertilizer
A3	CNG/Transport
A4	Cement & Steel Mill
A5	Captive Power
A6	General Industries
A7	Domestic & Commercial Heating

The experts were asked to rank 7 sectors that consume Natural gas in Pakistan based on 3 criteria and their responses were recorded. The criteria include Total Demand from each sector, their total revenue collected and their contribution to country's Economy. The criterions are also denoted symbolically using Table 3. One important thing to be noted here is that all these criterions are positive or Benefit criteria. In our case we do not have any negative or cost criteria.

Table 3: Main Criteria used in study

C1	Total Demand
C2	Total Revenue Collected
C3	Contribution to country's Economy

Step 1: First up we convert the response recorded by expert into Fuzzy number using Table 1 conversion and we create a different matrix for each alternative and see how many experts have ranked each alternative as Very Low, Low, Average, and etc. and then we calculate the fuzzy Weights for each one as shown below:

Table 4: Calculationof Fuzzified Weights for A1 Sector

A1	Weights	Very Low			Weights	Low			Weights	Average			Weights	High			Weights	Very High			Sum	Fuzzified Weights		
		1	1	3		1	3	5		3	5	7		5	7	9		7	7	9				
C1	0	0	0	0	1	1	3	5	3	9	15	21	5	25	35	45	1	7	7	9	10	4.2000	14.2857	5.6000
C2	0	0	0	0	1	1	3	5	4	12	20	28	5	25	35	45	0	0	0	0	10	3.8000	15.2632	5.1103
C3	0	0	0	0	0	0	0	0	4	12	20	28	5	25	35	45	1	7	7	9	10	4.4000	14.0909	5.8194

Similarly, for all other alternatives we create the same above shown matrix. The Fuzzified weights have been calculated using equations (12) (13). then we create a combined Decision matrix of all the experts using these Fuzzified Weights that we have calculated

$$Sum = \sum_{k=1}^{K} weights_k \qquad (12) \qquad\qquad FW = \frac{1}{Sum}\sum_{k=1}^{K} x_{ij}^{k} \qquad (13)$$

Where $\boldsymbol{x_{ij}}$ represents the combined fuzzy number for 1 individual attribute and the specific criteria while a, b and c are the 1st, 2^{nd,} and 3rd number in the fuzzy triangle. The summation and fuzzified weights will be calculated for all individual values of a, b, and c in each $\boldsymbol{x_{ij}}$.k index runs from 0 to K where K represents the total number of decisions in this case which is 5. As a result of this we get the combined Decision Matrix by inserting all the Fuzzified weights in the matrix as shown below:

Table 5: Combined Decision Matrix with Fuzzified Weights

Combined Decision Matrix									
	C1+			C2+			C3+		
A1	4.200	3.800	4.400	14.286	15.263	14.091	5.600	5.110	5.819
A2	4.200	3.600	4.600	14.762	15.556	14.348	5.555	4.886	5.994
A3	3.000	3.400	2.800	14.000	14.706	16.429	4.000	4.556	4.017
A4	2.400	2.800	2.800	16.667	16.429	17.143	3.240	3.835	3.967
A5	4.333	3.909	3.600	12.692	16.116	15.556	5.752	5.274	4.886
A6	3.800	4.000	3.800	15.263	15.000	15.263	5.110	5.333	5.110
A7	4.600	3.600	2.800	13.043	13.889	15.000	5.903	4.608	3.533
Cj*	4.600	4.600	4.600	17.143	17.143	17.143	5.994	5.994	5.994

$$c_j^* = \max_i\{c_{ij}\} \quad (14) \qquad \tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad (15)$$

$$a_j^- = \min_i\{a_{ij}\} \quad (16) \qquad \tilde{r}_{ij} = \left(\frac{a_j^-}{a_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{c_{ij}}\right) \quad (17)$$

Step 2: In this step we first normalize our decision matrix using the formulas in equation (14) and (15). For this we compute the cj* for benefit criteria and aj- for cost criteria. Since we already said that there are no cost criterions in this project, we will use the cj* value for to calculate the normalized decision matrix. The result in shown in Appendix BTable B1.

$$\tilde{v}_{ij} = \tilde{r}_{ij \times Wj} \quad (18)$$

Step 3: Next up we need to construct weighted normalized fuzzy decision matrix. So, for this we first calculate the combined weightage to the criterions assigned by our experts. In the first of the questionnaire the experts were also asked to rate our criterions according to the same attributes of importance. We first convert the attributes using Table 1 and then using the formulas in equations 12, 13 we find the weightage of our criterions in fuzzy numbers, similar to step 1. This is shown below in Appendix B Table B2:

After that we multiply the combined decision matrix and with their individual weights using the formulas in equation (18) and using property 1/ equation (11) mentioned earlier to calculate the weighted normalized Fuzzy decision matrix

Step 4: Next up we calculate the Fuzzy Positive Ideal solution (FPIS) and Fuzzy Negative Ideal solution (FNIS) using the formulas in equation (10). But before that we need to find the A* and A^- using the equation (19) given below:

$$A^* = (v_1^*, v_{2,}^* \ldots\ldots v_n^*), where\ v_j^* = \max_i\{\tilde{v}_{ij}\} \quad (19)$$

$$A^- = (v_1^-, v_{2,}^- \ldots\ldots v_n^-), where\ v_j^- = \min_i\{\tilde{v}_{ij}\}$$

Step 5: Next up we calculate separation measures. The distance of each alternative from *A** and A^-that is Di* and Di^- using the equations (20) and (21):

$$d_i^* = \sum_{j=1}^{n} d\,(\tilde{v}_{ij}, \tilde{v}*_{j)} \quad (20) \qquad d_i^- = \sum_{j=1}^{n} d\,(\tilde{v}_{ij}, \tilde{v}-_{j)} \quad (21)$$

Step 6: Calculate similarities to ideal solution. This is done by using the following equation (22). After calculating the Closeness Coefficient or CCi* values we rank the sectors or alternatives according to the highest values of CCi* in ascending order

$$cc_i^* = \frac{d_i^-}{(d_i^* + d_i^-)} \quad (22)$$

4. Results and Discussion

The forecasting techniques applied generated significant insights relating the demand and supply for Natural Gas in Southern Pakistan. The modeling technique which used seasonality to achieve a regression model forecasted Natural Gas demand for the years 2021-2023. The monthly Gas Demands are shown in the table in Appendix A Table A1.

The highlighted column displays the seasonalized forecasts for each month from 2021-23. The following data was then visualized graphically to understand the behavior of the actual demand and the forecasted demand of Natural Gas.

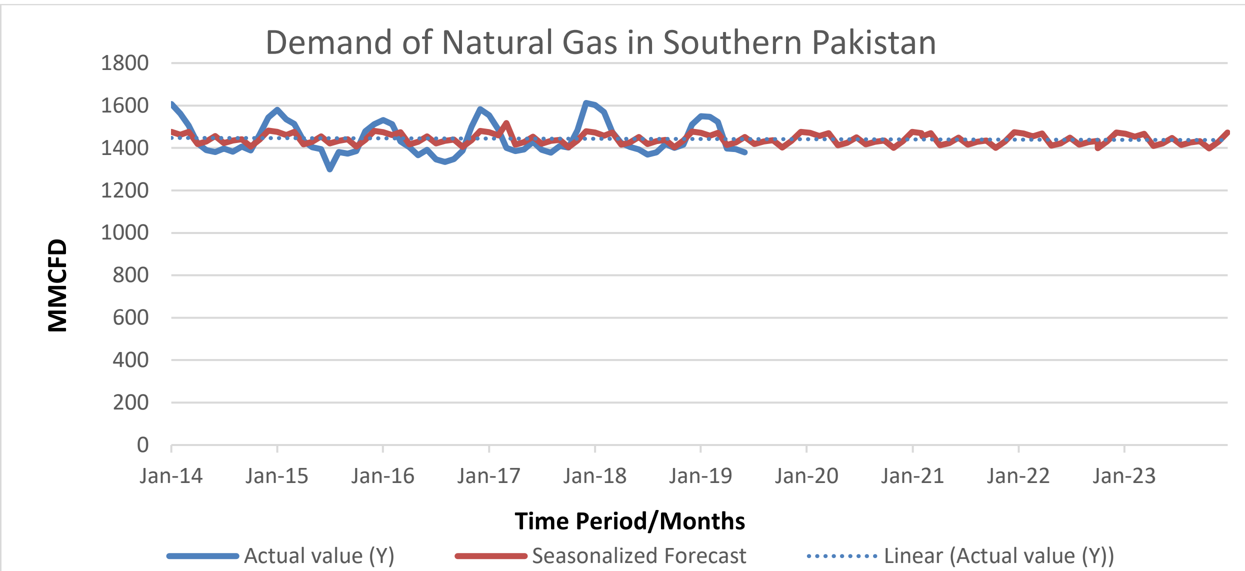

Figure 3: Demand of Natural Gas in Southern Pakistan

The peaks of both actual values of demand and the forecasted values coincide with one another on the graph. This shows us that since both the graphs follow a similar trend, the demand for natural gas has been forecasted significantly accurate. Furthermore, the trend shows a hike in the natural gas demand during winters in Pakistan. This reflects the fact that more Natural Gas is required by consumers for heating purposes in winters. The trend shows that for the years to come, the demand for natural gas will exceed 1400MMCFD every month with an average monthly demand of 1437MMCFD**.**

(Khan, 2015)studied the natural gas demand in Pakistan, where the study concluded an average increase of 3.07% in demand every year with a demand of 304,821MMCFT in 2020. The tools used in the study were econometric tools like GDP per capita and population growth in Pakistan. However, as our study shows, Southern Pakistan's forecasted demand does not change significantly because Power Sector companies like Kotari Power plant has closed down, whereas consumers like Fauji Fertilizer in Fertilizer Industry will end their contract with SSGC in 2021. Therefore, our model does not show significant percentage increase every year. An average of 1437MMCFD will be consumed monthly in the next three years to come.

The supply of Natural Gas was also forecasted using seasonality as a factor. The results of Natural Gas Supply forecasts are shown in Appendix A Table A2.

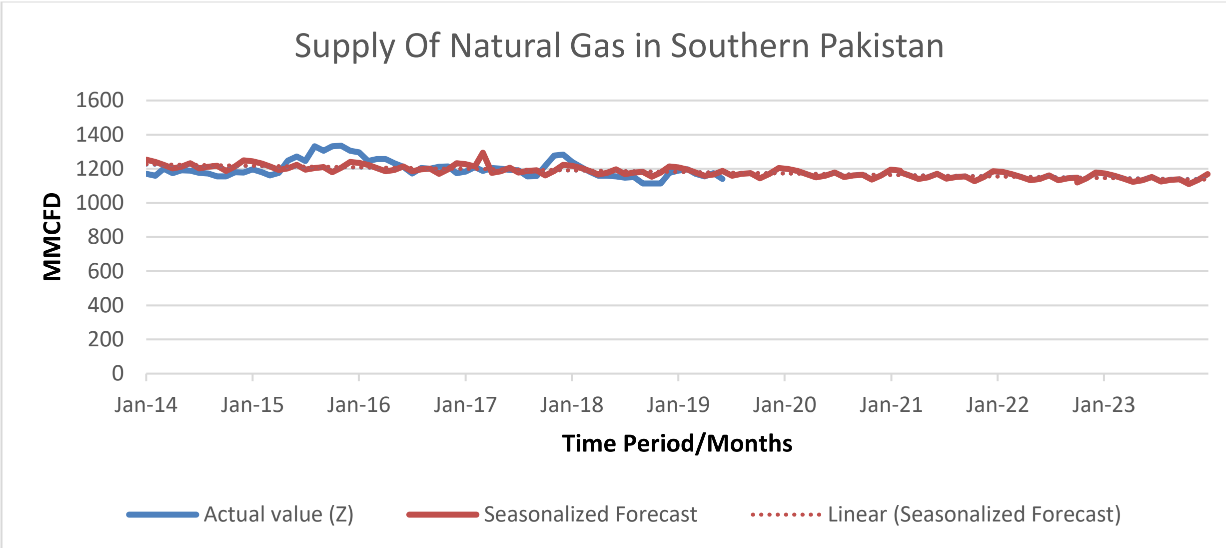

Figure 4: Supply of Natural Gas in Southern Pakistan

The actual monthly supply and the seasonalized forecasts coincide to a significant extent, thus, confirming the accuracy of this model. The forecasted monthly supply for Natural Gas is approximately **1150MMCFD** from all gas fields selling Natural Gas to SSGC.

The most significant finding of this model is the difference between monthly projected Natural Gas demand and supply in Southern Pakistan. The average monthly supply of Natural Gas varies around 1150MMCFD whereas the demand is approximately 1430MMCFD. This produces a shortfallof approximately **280 MMCFD.** These findings are visualized in the figure below.

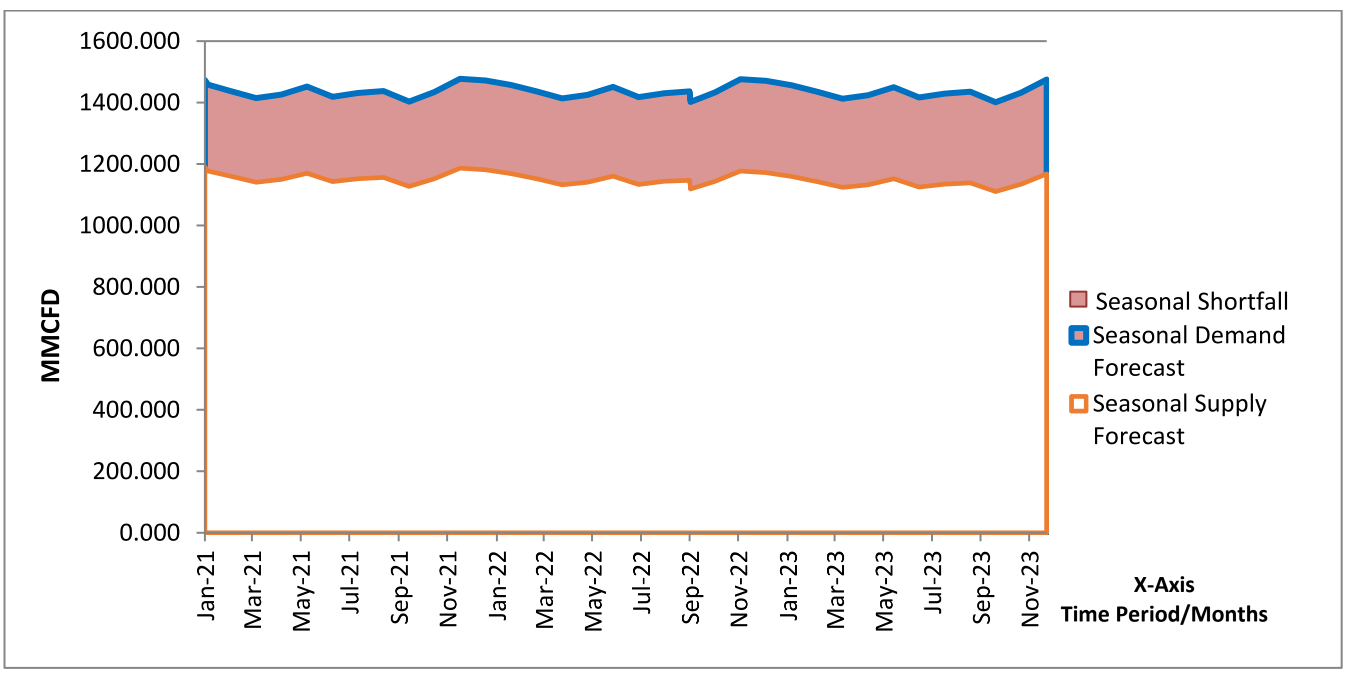

Figure 5: Shortfall of Natural Gas in Southern Pakistan

The shaded region in the graph above shows the shortfall of Natural Gas in Southern Pakistan. The shortfall is the difference between the predicted capacity or supply of Natural Gas and the forecasted Demand of Natural Gas by all sectors. This reflects a significant problem that needs to be addressed by the state before Natural Gas reserves exhaust in the country and impacts economic growth.

After implementing all the steps of Fuzzy TOPSIS as mentioned in the earlier section of Fuzzy TOPSIS we eventually reach some interesting results. First let us discuss some of the intermediate results. As stated earlier we calculated the weighted normalized Fuzzy decision matrix using equation 18 and property (1). After that, the next step is to calculate the A* and A^- from the weighted normalized matrix using equation (19). The results are shown below:

Table 6: Weighted Normalized Decision Matrix

Weighted Normalized Decision Matrix									
	C1+			C2+			C3+		
A1	0.822	8.261	1.243	0.333	8.904	0.164	0.841	8.526	0.680
A2	0.822	7.826	1.300	0.344	9.074	0.167	0.834	8.151	0.700
A3	0.587	7.391	0.791	0.327	8.578	0.192	0.601	7.601	0.469
A4	0.470	6.087	0.791	0.389	9.583	0.200	0.486	6.398	0.463
A5	0.848	8.498	1.017	0.296	9.401	0.181	0.864	8.799	0.571
A6	0.743	8.696	1.074	0.356	8.750	0.178	0.767	8.898	0.597
A7	0.900	7.826	0.791	0.304	8.102	0.175	0.886	7.688	0.413
A*	0.90	8.70	1.30	0.39	9.58	0.20	0.89	8.90	0.70
A-	0.47	6.09	0.79	0.30	8.10	0.16	0.49	6.40	0.41

The above results are then used to calculate Fuzzy Positive Ideal solution and Fuzzy Negative Ideal solution using the equation (11) and values of A* and A^-. These are crucial in calculating the ideal separation measure Di* and Di-, the results of which are shown below in Appendix B Table B3 and Table B4.

Next up we calculate the closeness coefficient from our separation measures and see which sector has the most importance according to experts who responded to the questionnaire. The results are shown below, and it can be clearly seen from the chart that sector A5 has been rated the highest priority followed by sector A6.

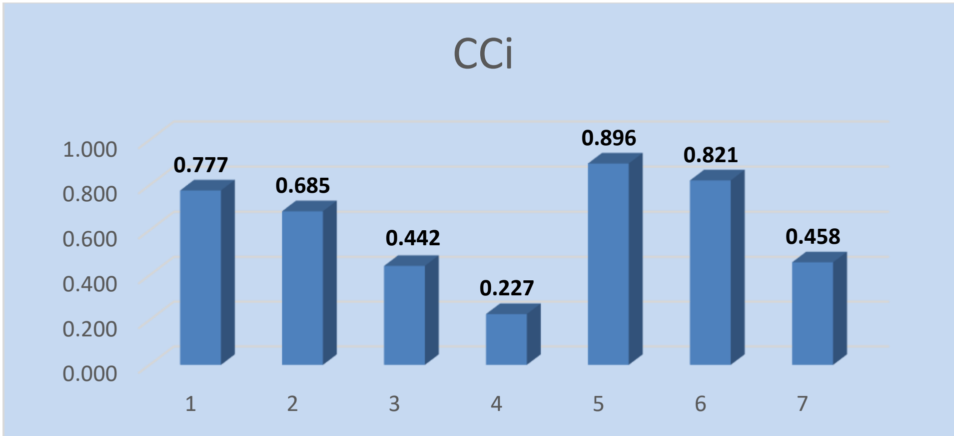

Figure 6: Closeness Coefficient Values

Based on these values of closeness coefficient we rank our alternatives in descending order. The sector with the highest value is ranked as the top priority and then rest follow below it. The sectors are ranked and shown below. It is clearly evident that sectors A5 and A6 that include Captive power and General industries respectively are ranked very highly with power generation and fertilizer industry following just behind them. Sectors like Transport as CNG, Steel Mill and Cement Industry are ranked at the bottom of the table with low priorities.

Table 7: Ranking of Sectors in Ascending Order

SECTORS	RANK
CAPTIVE POWER	1
GENERAL INDUSTRIES	2
ELECTRICITY GENERATION	3
FERTILIZER	4
DOMESTIC & COMMERCIAL HEATING	5
CNG/TRANSPORT	6
CEMENT & STEEL MILL	7

5. Recommendations

After completing our analysis on both fronts that includes forecasting future demand from past historical data using linear regression model and incorporating seasonality factor, we conclude the past our demand has an increasing trend from the last decade and will continue that trend in future. Incorporating the population growth factor of Pakistan will further confirm this increasing trend. Secondly, we have not discovered any recent new reserves of natural gas in the last decade and our current reserves are depleting fast which is evident from the supply chart shown in Figure 10. The trend is a decreasing one and we are slowly and gradually moving towards a period where we will eventually have no gas reserves left in future. Our research only covers the provinces of Sindh and Balochistan, if we were to estimate the figures for entire country, we can take 1.25 times the figure of Sindh and Balochistan for Punjab and KPK. This maybe a very naïve and rough estimate but it will help reach some informant and key insights. As of 2017, Pakistan's Natural Gas reserves accounted to **19 trillion cubic feet (TCF).**(worldometer, 2017)**.** These reserves may as well run out within the next 15 years if Pakistan does not adapt to alternative energy resources preferable renewable energysources. This is pretty alarming as this will halt the economic progress of the country, increasing import bill as now natural gas will be imported and will have adverse effects on balance of payment position. Therefore, we conclude something must be done to rectify this as this can be a major issue in future

Hence, we come to the second part of our analysis which is ranking of priority sectors that consume natural gas. Basically, we have now concluded that if we cannot increase our supply of natural gas the next best thing is that we use it efficiently and more carefully. This is means evaluating priority of each sector that has significant demand of natural gas and then only supplying to those high priority sectors. Therefore, we implemented a Fuzzy TOPSIS approach to rank the major sectors of natural gas demand. From the results of Fuzzy TOPSIS model we can conclude that Captive Power sector has been ranked with the highest priority. Captive Power are industries that generate their own power using natural gas. Following this are sectors General Industries, Electricity generation (primarily K- Electric) and fertilizer industry. All these sectors are ranked highly by all model based on the expert opinions. Transport (as CNG in cars) and industries like Steel Mill and Cement have been ranked at the bottom of the table. If we look into the demand for Steel Mill and Cement sector in the last 5 years, their demand is pretty low and has not increased much over the years. So even if we do not supply gas to that sector there would not be any drastic improvements in the shortfall we incur. Whereas if we look into the transport sector, the demand for that sector is significant enough while it has been ranked very low on the TOPSIS model by our experts. Furthermore, this sector also has some substitutes available like petrol, diesel or even hybrid cars now are in the market. Hence, we can conclude that if we do not supply natural gas to this sector this will help us reduce the shortfall and we will be using our remaining gas in a more efficient manner. The best recommended strategy would be for the Government to ban using natural gas as CNG in cars.

The two methods to address natural gas shortfall is by reducing the demand or increasing its supply. To address the ever-increasing demand of natural gas in short run, the state shall increase import of Regasified Liquefied Natural Gas to minimize the shortfall of natural gas. Furthermore, to address a long run shortfall of natural gas, the state shall initiate policies and schemes to attract more investment in drilling opportunities in different parts of Pakistan. The government shall offer tax concessions, relaxation in variable costs to investors so that drilling projects increase in Pakistan to grow Pakistan's Natural Gas reserves. Another way to minimize the shortfall of Natural Gas is by minimizing the wastage of Natural Gas. The most significant type of wastage is the Unaccounted-for Gas (UFG) in Pakistan. This is the proportion of Natural Gas that is wasted or not accounted for due to measurement errors, leakages, and thefts. A significant proportion of 17% of Natural Gas was unaccounted for in FY 2019-20. Therefore, in order to reduce the shortfall further, measures shall be taken to reduce the UFG to approximately 6% in order to ensure reduced wastage of Natural Gas and greater fulfillment of Natural Gas demand.

The demand of Natural Gas also needs be addressed in order to reduce shortfall and to maximize the life of current natural gas reserves of Pakistan. To do so, the state shall work on projects that give rise to alternative energy resources preferably renewable energy sources like hydel or solar. Also, reallocation of natural gas shall be done for CNG and Cement Industry. These industries are low on the priority list as shown by our analysis;hencetheir demand shall be switched to other alternative energy sources in order to reduce the over consumption of Natural Gas.

A greater optimization in the allocation of Natural Gas to particular sectors is required based on the significance to the economy of each sector.

6. Conclusion

The study aimed at discussing and analyzing the current situation of Natural Gas sector in Pakistan. The government has introduced and executed multiple policies since 2012 to counter the shortfall of Natural Gas, however, it failed to actually achieve the desired goal. Since 2010, the shortfall of natural gas in Pakistan has increased yearly because the demand continued to ride, while supply decreased since Pakistan has failed to explore and drill any further gas reserves. Baluchistan is considered as a valuable source of hydrocarbon reserves but due to political instability no drilling activity has been done in that area. Considering Pakistan as a developing country with varying levels of economic growth, any disruption in that economic growth will affect the economy drastically, therefore, the current trends of natural gas need to be studied in order to plan for the future usage and to invest on any new alternative energy sources.Therefore, this study aimed at predicting the demand of natural gas in Pakistan using certain econometric measures and compares it with forecasted supply in the future. The study approached the classic demand and supply problem to show the significant factor of scarcity of resources by using Linear Regression taking into further account the influence of seasonality. The exact demand and supply figures of last 6 years were tabulated and processed for seasonality to form a linear equation between Time Period and the actual value in MMCFD. Using the past data, a regression line was constructed which predicted monthly natural gas demand for the next three years. To compare it with the supply, we applied similar approach on natural gas supply in Southern Pakistan which is mainly from indigenous gas from Baluchistan and Sindh Gas Fields like Bhit and Kadanwari. The study forecasts a shortfall of 280MMCFD monthly which shows that a drastic shortfall is forecasted in the upcoming years in Southern Pakistan. The study concludes that Pakistan needs to find alternative sources of energy to meet the primary energy demands of multiple industries. Another way to deal with the shortfall is to reallocate Natural Gas to more important sectors and divert least prior sectors to other energy sources. The study then analyzes each sector that consumes Natural Gas in Pakistan using the FUZZY TOPSIS based on opinion of the experts working in the Natural Gas Industry. These experts belong to companies that distribute natural gas and petroleum throughout the country and have an ample amount of experience in the industry to know the technical and economic aspects of Natural Gas Sector in Pakistan. The survey concluded that Power Generation Industries are of utmost important as seen from previous data where Power Generation consumes around 38% of entire Natural Gas supply every year. It concludes that sectors like Captive Power and Power Generation are of utmost prioritywith cement industries and CNG being the least important sectors for the economy. Therefore, our study concludes that to reduce the shortfall, the state needs to reallocate their natural gas resources to the more important sectors and look to provide alternative energy sources to other industries. Alongside, a comprehensive policy regarding investments in drilling shall be introduced to increase the natural gas reserves in the longer run to increase overall supplies of Natural Gas. The study is of utmost significance to the economy of Pakistan as natural gas consists of 38% of the entire energy mix. Moreover, Pakistan's proportion of Unaccounted for Gas needs to be reduced by initiating projects to minimize theft and wastage in Pakistan and reduce leakage of Gas. To divert demand from CNG industries, prices of CNG can be increased to match the prices of Petrol and other types of fuel for vehicles. This way, consumers will shift to other fuels that will not compromise the performance of vehicles like it happens in the case of CNG. Therefore, this study finally concludes that there is a desperate need for Pakistan's authorities to swiftly make and implement policies to counter the increasing shortfall of Natural Gas before it exhausts and negatively affects the economic growth of Pakistan.

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Appendix A:

Table A1: Demand Forecast for period 2021-23

	DEMANDFORECASTS FOR FUTURE PERIODS FROM 2021-23		
	Un seasonalized forecast	**Seasonal index**	**Seasonalized forecast**
JAN-21	1439.467	1.023	1472.575
FEB-21	1439.377	1.013	**1458.089**
MAR-21	1439.287	0.999	**1437.847**
APR-21	1439.197	0.983	**1414.730**
MAY-21	1439.107	0.991	**1426.155**
JUN-21	1439.017	1.009	**1451.968**
JUL-21	1438.926	0.986	**1418.781**
AUG-21	1438.836	0.995	**1431.642**
SEP-21	1438.746	0.999	**1437.308**
OCT-21	1438.656	0.975	**1402.690**
NOV-21	1438.566	0.997	**1434.250**
DEC-21	1438.476	1.027	**1477.315**
JAN-22	1438.386	1.023	**1471.469**
FEB-22	1438.296	1.013	**1456.994**
MAR-22	1438.206	0.999	**1436.768**
APR-22	1438.116	0.983	**1413.668**
MAY-22	1438.026	0.991	**1425.084**
JUN-22	1437.936	1.009	**1450.877**
JUL-22	1437.846	0.986	**1417.716**
AUG-22	1437.756	0.995	**1430.567**
SEP-22	1437.666	0.999	**1436.228**
OCT-22	1437.575	0.975	**1401.636**
NOV-22	1437.485	0.997	**1433.173**
DEC-22	1437.395	1.027	**1476.205**
JAN-23	1437.305	1.023	**1470.363**
FEB-23	1437.215	1.013	**1455.899**
MAR-23	1437.125	0.999	**1435.688**
APR-23	1437.035	0.983	**1412.606**
MAY-23	1436.945	0.991	**1424.013**
JUN-23	1436.855	1.009	**1449.787**
JUL-23	1436.765	0.986	**1416.650**
AUG-23	1436.675	0.995	**1429.491**
SEP-23	1436.585	0.999	**1435.148**
OCT-23	1436.495	0.975	**1400.582**
NOV-23	1436.405	0.997	**1432.095**
DEC-23	1436.315	1.027	**1475.095**

Table A2: Supply Forecast for period 2021-23

	SUPPLY FORECAST FOR FUTURE PERIODS FROM 2021-23		
	Un seasonalized forecast	**Seasonal index**	**Seasonalized forecast**
JAN-21	1163.132	1.023	**1189.884**
FEB-21	1162.396	1.013	**1177.507**
MAR-21	1161.660	0.999	**1160.499**
APR-21	1160.924	0.983	**1141.189**
MAY-21	1160.189	0.991	**1149.747**
JUN-21	1159.453	1.009	**1169.888**
JUL-21	1158.717	0.986	**1142.495**
AUG-21	1157.981	0.995	**1152.191**
SEP-21	1157.245	0.999	**1156.088**
OCT-21	1156.509	0.975	**1127.596**
NOV-21	1155.773	0.997	**1152.306**
DEC-21	1155.037	1.027	**1186.223**
JAN-22	1154.302	1.023	**1180.850**
FEB-22	1153.566	1.013	**1168.562**
MAR-22	1152.830	0.999	**1151.677**
APR-22	1152.094	0.983	**1132.508**
MAY-22	1151.358	0.991	**1140.996**
JUN-22	1150.622	1.009	**1160.978**
JUL-22	1149.886	0.986	**1133.788**
AUG-22	1149.150	0.995	**1143.405**
SEP-22	1148.415	0.999	**1147.266**
OCT-22	1147.679	0.975	**1118.987**
NOV-22	1146.943	0.997	**1143.502**
DEC-22	1146.207	1.027	**1177.155**
JAN-23	1145.471	1.023	**1171.817**
FEB-23	1144.735	1.013	**1159.617**
MAR-23	1143.999	0.999	**1142.855**
APR-23	1143.263	0.983	**1123.828**
MAY-23	1142.528	0.991	**1132.245**
JUN-23	1141.792	1.009	**1152.068**
JUL-23	1141.056	0.986	**1125.081**
AUG-23	1140.320	0.995	**1134.618**
SEP-23	1139.584	0.999	**1138.445**
OCT-23	1138.848	0.975	**1110.377**
NOV-23	1138.112	0.997	**1134.698**
DEC-23	1137.376	1.027	**1168.086**

Appendix B:

List of Abbreviations

BTU	British Thermal unit
RLNG	Regasified Liquefied Natural Gas
CNG	Compressed Natural Gas
UFG	Unaccounted for Gas
MMCFD	Million Standard Cubic Feet per day
SSGC	Sui Southern Gas Company Ltd
SNGPL	Sui Northern Gas Pipelines Ltd.
TCF	Trillion Cubic Feet

Table B1: Normalized Decision Matrix

	Normalized Decision Matrix								
	C1+			C2+			C3+		
A1	0.913	0.826	0.957	0.833	0.890	0.822	0.934	0.853	0.971
A2	0.913	0.783	1.000	0.861	0.907	0.837	0.927	0.815	1.000
A3	0.652	0.739	0.609	0.817	0.858	0.958	0.667	0.760	0.670
A4	0.522	0.609	0.609	0.972	0.958	1.000	0.541	0.640	0.662
A5	0.942	0.850	0.783	0.740	0.940	0.907	0.960	0.880	0.815
A6	0.826	0.870	0.826	0.890	0.875	0.890	0.853	0.890	0.853
A7	1.000	0.783	0.609	0.761	0.810	0.875	0.985	0.769	0.589

Table B2: Fuzzified Weight calculation for Decision Criterions

	Weights	**Very Low**			**Weights**	**Low**			**Weights**	**Average**		
		1	**1**	**3**		**1**	**3**	**5**		**3**	**5**	**7**
C1	0	0	0	0	1	0	0	0	2	2	2	6
C2	0	0	0	0	0	0	0	0	8	2	2	0
C3	0	0	0	0	0	0	0	0	3	2	2	0

Weights	**High**			**Weights**	**Very High**			**Sum**	**Fuzzified Weights**		
	5	**7**	**9**		**7**	**7**	**9**				
7	7	7	7	0	0	0	0	10	0.9000	10.0000	1.3000
2	2	2	2	0	0	0	0	10	0.4000	10.0000	0.2000
7	7	7	7	0	0	0	0	10	0.9000	10.0000	0.7000

Table B3: Fuzzy Positive Ideal Solution

	Fuzzy Positive Ideal Solution (FPIS) Matrix			
	C1+	C2+	C3+	Di*
A1	0.257	0.394	0.217	0.868
A2	0.504	0.296	0.432	1.232
A3	0.828	0.581	0.778	2.188
A4	1.554	0.000	1.468	3.023
A5	0.201	0.119	0.095	0.415
A6	0.159	0.482	0.091	0.731
A7	0.582	0.857	0.718	2.157

Table B4: Fuzzy Negative Ideal Solution

	Fuzzy Negative Ideal Solution(FNIS) Matrix			
	C1+	C2+	C3+	Di-
A1	1.298	0.463	1.255	3.016
A2	1.066	0.562	1.045	2.673
A3	0.756	0.276	0.699	1.731
A4	0.000	0.857	0.029	0.886
A5	1.415	0.750	1.406	3.572
A6	1.523	0.376	1.456	3.355
A7	1.034	0.008	0.780	1.822

Table B5: Respondents Details for Fuzzy TOPSIS Model

Position	**Company**	**Experience in Years**
Deputy Manager	Sui Southern Gas Company	9
Chief Engineer Transmission	Sui Southern Gas Company	25
Chief Executive Officer	Gasco Engineering	23
Director Business Development	K- Electric	25
General Manager	Sui Southern Gas Company	30
Managing Director	City Fuel Gas Company	33
Mechanical Engineer	Sindh Nooriabad Power	6
Chief Engineer	Sui Southern Gas Company	10
Director Gas	Petroleum Division	15
Ex General Manager	Fauji Fertilizer Bin Qasim	35