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## ECOM6003 – Predictive Analytics in Business

## Assessment 1 - Project Proposal

# Analysing the Impact of determinants towards the Sustainable energy consumption and Achieving Sustainable Development Goals of Pakistan

## 1. Introduction

Energy is a very significant determinant in economic progress and one of main contributor to improving economic activity. Energy consumption results in the increased manufacturing processes which helps a country in expanding economic growth. The increase in economic expansion, technological advancement and urbanization results in the increase in energy consumption over time (Majeed & Tauqir, 2020). As a necessity of life, energy has a significant impact on economic growth and plays a very vital role in production of goods and services and ensuring populations wellbeing within any economy. The economic industrialisation, growing population, widespread urbanization and the increased consumption of electrical equipment in day-to-day life due to rising living standards have resulted in the increased electricity demand worldwide (NEPRA, 2018). Consequently, in Pakistan, Inefficient energy demand is increasing while the resources have been exploited over the years. With inefficient energy infrastructure, Pakistan is suffering from the issue of climate change and pollution. The exploitation of energy resources results from inefficient equipment, ineffective planning and energy market incompetence and pollution. The renewable energy adoption is regarded as one of the cleanest and sustainable way to fight with these challenges. The renewable energy minimizes the environmental impact as it reduces the carbon emissions into the environment resulting in less pollution. The renewable energy adoption also helps diversify the energy portfolio and enhance energy security compared to non-renewable energy sources (Al-Mulali et al., 2013).

The focus of this research is on SDG goal 7 i.e., to build infrastructure to ensure that all the underdeveloped countries have access to sustainable and clean energy as the energy sustainability and usage have a direct impact on the economic growth and environment of any country, SDG 11 i.e., making cities and human settlements inclusive, safe, resilient and sustainable as providing affordable and energy is essential for improving the living conditions in the urban areas, SDG goal 8 i.e., decent work and economic growth as the goal aim to provide sustainable economic growth, full and productive employment opportunities and decent work conditions for all. Providing affordable energy not only improves the urban living conditions but also helps the country industry to grow resulting in better and more employment opportunities for the people and economic growth of the country (UNDP, 2019). Well planned urbanization and efficient energy system results in resilient infrastructure and

fosters industry growth i.e., SDG goal 9, Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

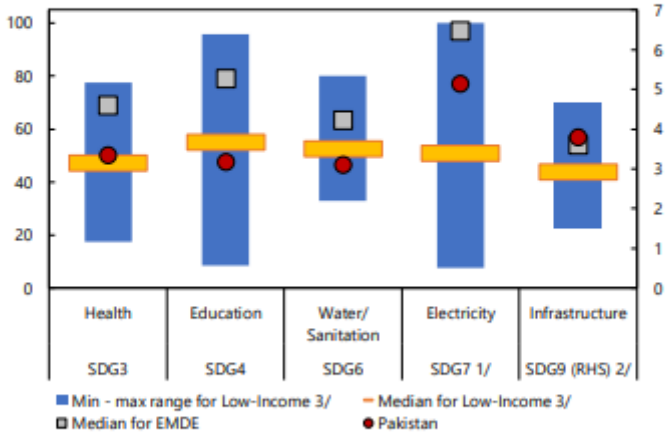
Energy consumption is one of the most important determinants for economic growth of the country and improves the standards of one's living (Felipe et al., 2019). Unplanned Urban growth and underdeveloped electricity network significantly effects the economy of Pakistan, leading to sudden load shedding and frequent power outages around the country. These disruptions are result of the growing demand for energy, which affects the overall stability and development of the economy. Furthermore, the process of urbanization in Europe took 150 years to increase from 10 % to 15% (Zhang, 2016), while the same transition has occurred in one third time in Pakistan. Rapid urbanization strains the existing infrastructure, which can lead to inefficiencies in the energy distribution and increased operational cost for the industries. The aim of this research is to model the Pakistan need for investment in sustainable and renewable energy production resources to achieve SDG goal 7, economic growth, better transition to urbanization and carbon emission in the environment and to see how these determinants get effected by the increased energy consumption. The aim of this research is to model the Pakistan need for investment in better energy production resources to achieve SDG goal 7, as the economic growth, better transition to urbanization and carbon dioxide emissions and low carbon electricity production significantly impacts and leads to increased energy consumption from renewable sources and leads people having access to sustainable and clean energy in Pakistan.

## 2. Motivation/Importance

Pakistan committed to 2030 SDGs agenda in 2015 and adopted the SDGS as part of their national development agenda in 2016. Although the social development and economic growth should go side by side, Pakistan has struggled to achieve balanced social development over the past decades. The primarily reason for this is due to rapid of population growth. Consequently, many of country's social indicators have not kept pace with the significant levels of economic growth, averaging 4 per cent per year (Ali, 2024). This disparity underscores the critical importance of Sustainable Development Goals and makes them a key priority for the Pakistan to ensure that economic progress translates to social benefits and addresses the critical challenges faced by the country.

While Pakistan has made some progress in achieving the goals of SDGs like poverty, accountability and transparency, women empowerment and gender equality, however, its current performance in the very critical sectors like electricity, education, infrastructure and health, lags a lot in comparison to its peers. Pakistan performance in energy sector i.e., SDG 7, infrastructure i.e., SDG 8 and Education i.e., SDG 4 is way below the median for the emerging market and developing economies with the performance the sectors of infrastructure and electricity is way below the median line, shown in the figure below, for countries with GDP per capita below US$3000, as measured by the SDGs indices.

**Figure 1. Pakistan's Performance in Selected SDGs**




Source: IMF staff calculations using Sachs and others (2019).
Notes: 1/ Access to electricity (percentage of population).
2/ Quality of overall infrastructure.
3/ Countries with GDP per capita below US$3,000.

Pakistan needs to put effort on the policy making and implementation to make growth in the sectors of energy and infrastructure. The SDG 7 which states providing clean, sustainable and affordable energy to everyone is very important for the economic and industrial growth of any country and is directly linked to SDGs goal 8 i.e., sustainable economic growth and productive employment of the country, SDGs goal 9, i.e., helping the country build resilient infrastructure and help growth in the industry, and SDGs goal 11 i.e., help the country build safe and sustainable cities where people can have good quality of life and good basic facilities.

## 3. Hypothesis

**H1:** Carbon emissions, economic growth, urbanization, and low carbon electricity production significantly impacts the energy consumption from renewable sources in Pakistan, and this relationship fosters the development of sustainable infrastructure for providing clean and sustainable energy to all the people of Pakistan.

## 4. Literature Review

Energy is considered a fundamental factor in development and production and plays a crucial role in driving the economic expansion. (Kraft & Kraft, 1978) in his study examined the relationship between energy and economic growth using novel econometric methods over the frequency of different time periods. The findings of the research indicated that although the energy is very important in production, the evidence of it directly impacting the economic growth were not found in the research. Nonetheless, several studies conducted over the past few decades have tried to

examine the relationship between energy consumption and economic growth (Bekun et al., 2020; Chiou-Wei et al., 2008; Narayan & Prasad, 2008). Even though, the studies suggest a positive relationship between the economic growth and energy consumption. However, the researchers were unable to reach to the consensus on the direction of causality between the economic progress and electricity consumption(Yoo, 2006).

In light to the fact that energy cost is directly linked to industrial growth, increased electricity consumption and urbanization, a lot of studies are being conducted by the researchers to study the impact of electricity consumption and sustainable development(Alam et al., 2007; Nate et al., 2021; Omer, 2008). This was illustrated by (Abbasi et al., 2021) who studied the effect of energy consumption, industrial growth, urbanization and CO2 emissions on the economic growth of Pakistan. The dynamic autoregressive distributed lag (ARDL) simulations approach was used to analyse the positive and negative changes of these determinants on the economic growth of Pakistan. The findings of this research indicates that the energy consumption, urbanization, industrial growth and CO2 emission positively impacts that the economic growth of Pakistan.

This point was further illustrated in the another study by (Ayinde et al., 2019) who analysed the effect of economic growth, industrialization and urbanization on energy consumption in Nigeria. Vector Error Correction Model (VECM) along with Granger causality was used for the analysis. The findings of the research indicate a long run casual relation between the GDP and energy consumption however, no short run causal relationship was observed between the energy consumption and any of the other variables. This could be implied by this research that the energy consumption has a stagnant long-term effect on the economic growth of the country.

(Al-Bajjali & Shamayleh, 2018) in another study analysed the determinants of electricity consumption in Jordan. The variables used in the study were GDP, electricity prices, population, structure of economy, urbanization and aggregate water consumption. Vector error correction model (VECM) with the cointegration test was used. The result of the study indicates that GDP, urbanization, water consumption and structure of economy has positively significant impact on the electricity consumption, while electricity prices have a significantly negative relationship with the electricity consumption (Al-Bajjali & Shamayleh, 2018).

## 5. Data sources

This study has utilized the datasets of different variables from 2001 to 2019. The variables that have been considered for this research are Energy consumption from-renewable sources, GDP, Urban Growth Rate, CO2 emissions, Share of electricity production from low carbon sources. The frequency of data used for this research is from 1985 to 2020 to maintain data consistency.

| | Determinants | Data source | Alternate sources |
|---|---|---|---|
| **Dependent Variables** | Energy consumption from-renewable sources | (Hannah Ritchie, 2020) | (*World Bank Open Data*, 2015) |
| **Independent Variables** | GDP | (*World Bank Open Data*, 2015) | (Statista, 4 July 2024)<br><br>(*Pakistan - GDP - real growth rate - Historical Data Graphs per Year*) |
| | Urban Growth Rate | (*Pakistan Urban Population 1960-2024*) | (*World Bank Open Data*, 2015) |
| | CO2 emissions | (Hannah Ritchie, 2020) | (*World Bank Open Data*, 2015) |
| | Share of electricity production from low carbon sources | (Hannah Ritchie, 2020) | (*Energy*, 2023)<br><br>(*World Bank Open Data*, 2015) |

### *5.1. Energy consumption from-renewable sources:*

Renewable energy here is the sum of hydropower, wind, solar, geothermal, modern biomass and wave and tidal energy (Hannah Ritchie, 2020). It plays a very important role in the lowering greenhouse gas emissions and promoting diversification in the energy network. Renewable energy consumption as a variable provides a framework for evaluating the effectives of factors promoting the sustainable energy use and would help us measuring the progressing towards the SDG7,

### *5.2. Economic Growth:*

The economic growth is one of the very important factors that influences the urbanization and energy consumption (Henderson, 2003). GDP i.e., gross domestic product is the independent variable in this research which has been used as proxy for measuring the economic growth of Pakistan as it measures the total value of all the good and services rendered with in a country within a specific period. It includes almost all the aspects of economic activity within the country such as investment, consumption, government spendings and net exports.

### *5.3. Urbanization:*

The urbanization process primary involves the migration of people from rural to urban area (Nations, 1997). The urban growth rate over the years from the 2001 to 2019 of population residing in urban areas is used a proxy to assess the level of urbanization. Urbanization typically leads to higher energy needs for residential,

industrial and commercial purposes. Well managed urbanization can stimulate economic growth by fostering investment and innovation and focusing on economic activities.

### *5.4. CO2 emissions:*

Co2 emission is the amount of carbon dioxide emitted per unit of energy production in the atmosphere and is very important variable as it can have adverse effects on the climate change and environment of a country. CO2 emission is the key contributor in global warming and climate change is crucial for achieving environmental sustainability. The dataset is consistent for all years and has no missing values.

### *5.5. Share of electricity production from low carbon sources*

Low carbon electricity is all the electricity that is produced from the renewable and nuclear sources which includes wind, hydropower, solar, biomass, wave, tidal etc. These sources are considered low carbon because they produce very little carbon dioxide during the process of electricity generation. Diversifying the energy mix with low carbon energy enhances the energy security and helps with the transitioning towards a sustainable energy system aligning with the SDG 7.

## 6. Modelling methodology

We will be using multi linear regression. Using the multi regression model would quantify the impact of determinants like GDP, Urban Growth Rate, CO2 emissions, share of electricity production from low carbon sources on the electricity consumption from renewable sources of Pakistan while exploring how other variables (e.g., economic activity, policies) influence electricity consumption. The initial model would be:

$Energy\ Consumption_{renewable\ sources} = \beta_0 + \beta_1$(Low carbon electricity production) + $\beta_2$(Pakistan GDP) + $\beta_3$(Urbanization) + $\beta_4$($CO_2$ emission ) + ϵ

Where, $\beta_0$ is the intercept while $\beta_1$, $\beta_2$, $\beta_3$ and $\beta_4$ are the coefficients of each independent variable with ϵ being the error term for the observation.

The ordinary least squares (OLS) regression will be applied to the dataset to estimate the coefficients $\beta_1$, $\beta_2$, $\beta_3$ and $\beta_4$ and by minimizing the squared residuals, the best fitting line will be applied through the data. Furthermore, hypothesis testing would be applied to test the p-value to reject the null hypothesis for all the Betas. Goodness to fit ($R^2$) would be evaluated to determine the proportion of variance in economic growth explained by the model. Lastly, homoscedasticity test might be applied to ensure that the residuals have constant variance.

## 7. Results

### *7.1. Descriptive statistics*

The sample size of 36 years has been considered for this research, to observe trends and patterns in renewable energy consumption and its determinants in Pakistan.

| | Dependent variable | Independent Variables | | | |
|---|---|---|---|---|---|
| | E_ConsRenew | CO2_emission | Low_CO2_elect | Pak_GDP | Urban Growth |
| Min | 25 | -5 | 26.40 | -1.30 | 1.80 |
| 1st Quartile | 30.10 | 0.450 | 33.40 | 2.925 | 2.625 |
| Median | 33.05 | 4.350 | 36.45 | 4.400 | 2.950 |
| Mean | 33.59 | 4.519 | 36.08 | 4.381 | 3.138 |
| 3rd Quartile | 36.83 | 8.075 | 37.665 | 5.650 | 3.725 |
| Max | 45.20 | 17 | 46.50 | 7.800 | 4.400 |

The percentage of Low-carbon electricity (Low_CO2_elec) ranges from 26.4% to 46.5% and has a mean of 36.08 includes nuclear and renewable technologies. Carbon dioxide emission (CO2_emission2) is the carbon dioxide emission resulting from the energy consumption and has a mean of 4.52. The data shows the CO2 emission has generally increased but there are some periods of emission reduction. Energy consumption from renewable resources (E_ConsRenew) is the energy consumption from renewable resources and has a mean of 33.59. The urban growth rate and Pakistan GDP has mean of 3.13 and 4.38 respectively.

### *7.2. Model estimations*

The multi linear regression model for our research is:

$Energy\ Consumption_{renewable\ sources} = \beta_0 + \beta_1$(Low carbon electricity production) + $\beta_2$(Pakistan GDP) + $\beta_3$(Urbanization) + $\beta_4(CO_2$ emission ) + ϵ

The multi linear regression model shows the relationship between the renewable consumption of energy and its determinants. The intercept has come out to be -7.6. The variable Urbanization shows coefficient of 2.13663 and the p value has come out to be 8.97e-09. The p value indicates a strong positive relationship between the urbanization energy consumption from renewable resources and, which suggests the urbanization shows greater demand of energy and significantly effects the increase in renewable energy consumption. Low carbon electricity production shows the coefficient of 0.93974 and the p value has come out to be 2e-16, which shows that the low carbon electricity production has a significant impact on the energy consumption from renewable resources. This could be implied that the increase in production of

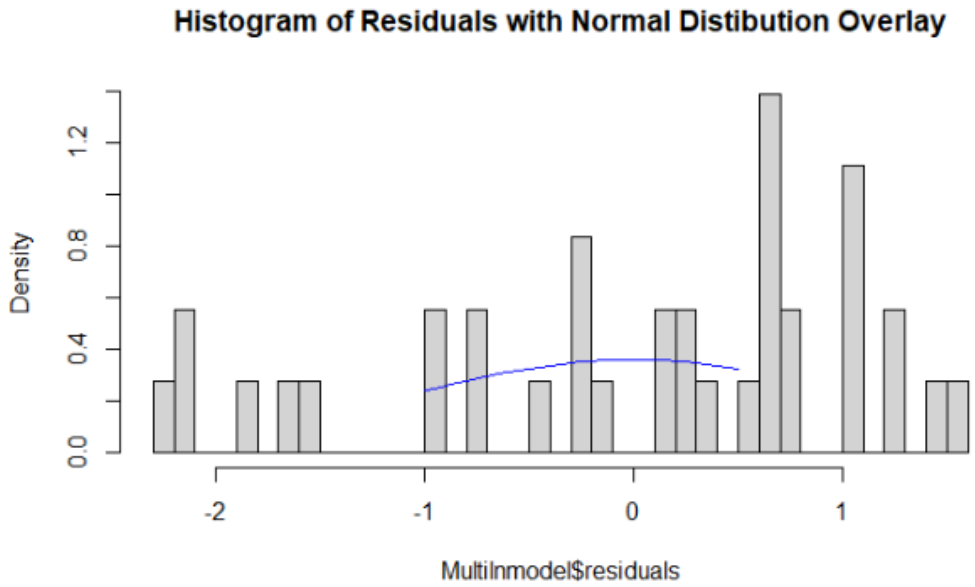
every unit of low carbon electricity, there is significant increase in renewable energy consumption which supports the hypothesis to invest in low carbon technology promotes the renewable consumption.

The carbon emission coefficient has come out to be 0.07401 and p value is 0.114424. The low p value implies that the carbon emission variable is not significant which means that the emission of carbon does not directly affect renewable energy consumption. The growth domestic product of Pakistan variable has a coefficient of 0.02576 and p value of 0.822559, which indicates that their no significant impact of economic growth on electricity consumption from renewable resources and suggests that the economic growth might not be the only factor to drive renewable energy consumption.

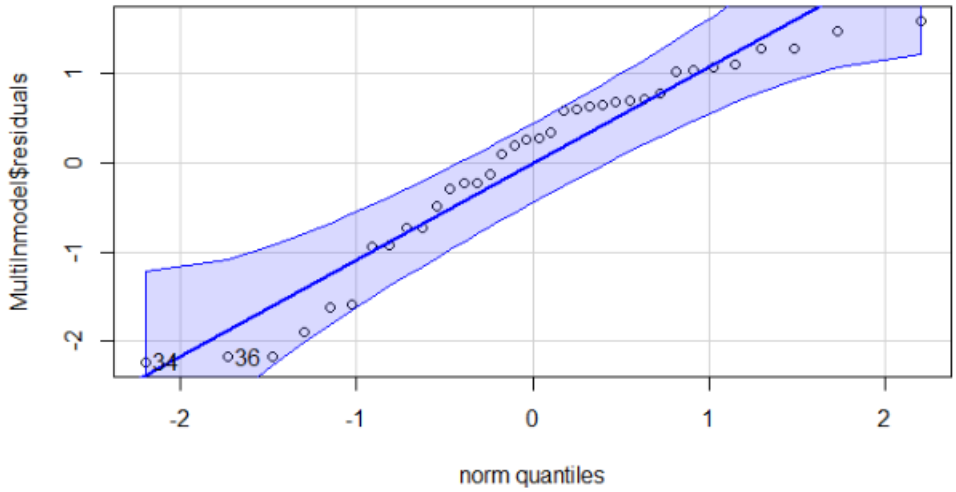
### *7.3. Model diagnostics*

Diagnostics tests performed:

- **Normality of Residuals:** The residuals don't follow the perfectly normal distribution. The distribution seems to be slightly skewed with more values clustering around 0 and 1, as shown in the figure below. , Jarque-Beta test gives p-value of 0.207, shows the residuals which do not deviate from normality and support the assumptions of model.




The QQ-plot further supports the observations of histogram, the deviation could be observed from normality especially at the tails of distribution suggesting outliers as shown in the figure below.

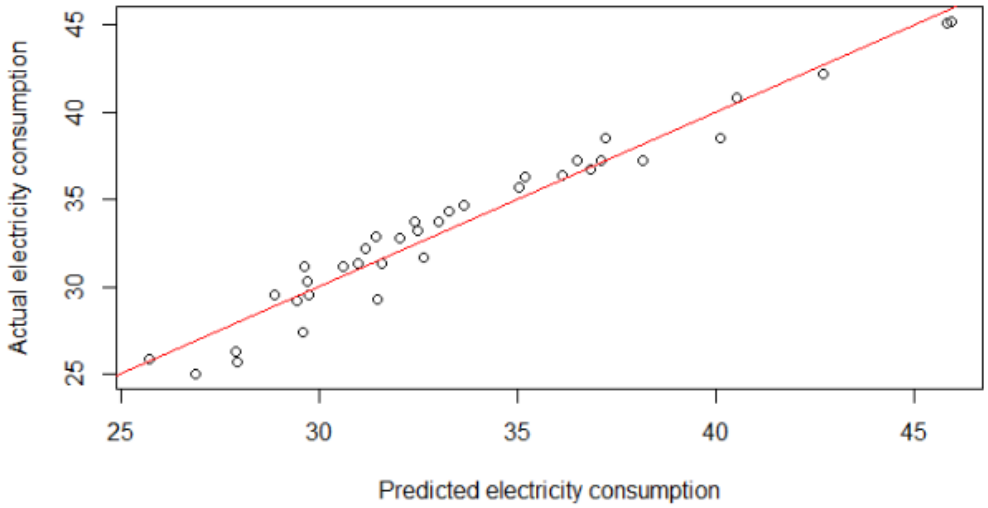



Jarque Bera Test was conducted to further evaluate the normality of the distribution. The test suggests that the p-value is > 0.05 thus we do not have enough evidence to reject the null hypothesis, i.e., the test suggests that residuals might be normally distributed however, the histogram and qqplot indicates deviations towards the tails suggesting the presence of potential outliers.

```
        Jarque Bera Test

data:  MultiInmodel$residuals
X-squared = 3.1503, df = 2, p-value = 0.207
```

- **Model Assessment:**
  The point is well aligned along the diagonal line within the plot although there are some outliers on the upper end of the plot. The alignment indicates that the model predicted values are close to the actual values indicating that that the model has strong prediction accuracy.




- **Homoscedasticity:** White test was conducted to test whether the variance of error is constant throughout the model. The t-stat has come out to be 21.89 while the p-value is 0.0387 which is less than 0.05 indicating that we reject null hypothesis, which indicates that there is presence of heteroscedasticity in the model.

  Breusch Pagan test shows p-value = 0.04095 which shows evidence of heteroscedasticity and require more examination in specification of model.
- **Incorporation of higher order terms:** Incorporating higher order fits improved the model performance. Low carbon electricity production, urban growth rate and CO2 emission become statistically significant while Pakistan GDP with the p value of 0.0688 shows small positive affect in the dependent variable.

```
Call:
lm(formula = E_ConsRenew ~ Low_CO2_elec + Pak_GDP + urban_growth_r +
    CO2_emission + fits2 + fits3, data = codata)

Residuals:
     Min       1Q   Median       3Q      Max
-2.18489 -0.51350  0.09172  0.65672  1.69663

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    -1.962e+02  9.757e+01  -2.011   0.0537 .
Low_CO2_elec    9.858e+00  4.775e+00   2.064   0.0480 *
Pak_GDP         3.249e-01  1.719e-01   1.890   0.0688 .
urban_growth_r  2.292e+01  1.108e+01   2.070   0.0475 *
CO2_emission    7.974e-01  3.872e-01   2.060   0.0485 *
fits2          -2.522e-01  1.434e-01  -1.759   0.0891 .
fits3           2.172e-03  1.321e-03   1.644   0.1110
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.048 on 29 degrees of freedom
Multiple R-squared:  0.965,     Adjusted R-squared:  0.9577
F-statistic: 133.1 on 6 and 29 DF,  p-value: < 2.2e-16
```

### *7.4. Model selection*

The model we have selected is a multiple linear regression model which shows:

$$E\_ConsRenew = -7.46282 + 0.93974(Low\_CO2\_elec) + 0.02576(\text{Pak\_GDP}) + 2.13663(\text{urban\_growth\_r}) + 0.07401(CO2\_\text{emission}) + \epsilon$$

Where,

- $E\_ConsRenew = Energy\ consumption\ from\ renewable\ resources$
- $Low\_CO2\_elec = Low\ carbon\ electricity\ production$
- $\text{Pak\_GDP} = GDP\ of\ Pakistan$
- $\text{urban\_growth\_r} = Urban\ growth\ rate$
- $CO2\_\text{emission} = Carbon\ emissions$
- $\beta 0 = Intercept$
- $\beta 1, \beta 2, \beta 3, \beta 4 = Coefficients\ for\ each\ predictor$
- $\epsilon = Error\ term.$

Residuals (Min: -2.2376, Max: 1.5947) appears to be distributed around zero. Two variables, i.e., low carbon electricity production and urban growth shows statistical significance, while Pakistan GDP and CO2 emission are not statistically significant variables. The R-square has come out to be 94.67% indicating that the model can explain the 95.28% of the variance in renewable energy consumption. However, F-stats is 156.4 while the p-value has come out to be <2.2e-16, indicating that the overall model is statistically significant.

## 8. Discussion

### *8.1. Interpretation of results*

The regression analysis findings show few key insights of renewable energy consumption determinant in Pakistan. For production of low carbon electricity, the strong positive coefficient of 0.93974 shows its critical role in promoting the use of renewable energy. This shows that in Pakistan, as low carbon energy production increases, it can significantly increase the consumption of renewable energy which aligns with efforts of global sustainability. Urban growth of 2.13663 also seem like significant factor which suggest that increase in urbanization increases demand for energy which necessitates a shift towards renewable energy resources to meet sustainable demand. Hence the lack of important effects from Co2 emission and GDP shows that the growth of economy alone does not guarantee the increase in

consumption of renewable energy and the impact of emission of direct environment may not immediately impact consumption patterns.

In this study, the regression analysis is done to highlight the multifaceted relationship in Pakistan, among renewable energy consumption and its determinants. The model shows that urbanization and production of low carbon electricity are main drivers of uptake of renewable energy which shows the significance of transition towards sources of cleaner energy to get Sustainable Development Goal (SDG-7) and ensures access to reliable, affordable, modern and sustainable energy for all.

The important effect of urban growth shows estimates of 2.13663 and p value of 8.97e-09 underscores the urban areas roles as catalyst for infrastructure of renewable energy. They can be designed to effectively incorporate renewable energy systems as cities expand. Strategic planning of urban emphasize the solution of sustainable energy that can enhance reliability and accessibility, that fosters an environment which support SDG-7.

Low carbon electricity production coefficients show a strong positive relationship, estimate 0.93974 and p value of 2e-16 with renewable energy consumption. The policies whose aim is to increase the low carbon energy share in national grid could impact significantly which elevate the renewable energy resources adoption. The Government can provide facility of increasing renewable energy consumption by investing in technologies like wind and solar and aligns with target of SDG-7 to increase the renewable energy share in global energy mix.

The statistical significance of lack for GDP with p value of 0.822559 and non-significant positive relationship with Co2 emission with p value of 0.114424 shows that alone economic growth does not correlate with increased consumption of renewable energy.

### *8.2. Limitations of Results*

As the model gives valuable insights there must be several limitations which need to be noted:

- There could be potential outlier triggering the variability of error in the model as evident from the results of white test.
- Furthermore, there is a limitation of analysis by availability of data which might not capture all related factors influencing consumption of renewable energy. Most of the public data is only available from 1985 or 1990 till 2020.
- the assumptions cover linear regression like independence of residuals and homoscedasticity while more efficient models could be used like time series and causality analysis to study the better interrelated relationship among the variables.
- The historical data considered in this model is up to 2020. However, energy landscape is Fastly evolving and the latest development on it might not be considered.

### *8.3. Hypothesis*

By using linear Hypothesis () conducted to compare the restricted model, where all the predictors are estimated to be zero against the actual model. RSS is significantly high i.e. 42.92 while the p-value is < 2.2e-16. The extremely low p value indicates that the model with predictors provide significantly better fit to the data. Furthermore, test confirms that one of predictors at least significantly influence consumption of renewable energy. F-statistics of 156.4 shows that overall model is statistically significant.

```
Linear hypothesis test

Hypothesis:
Low_CO2_elec = 0
Pak_GDP = 0
urban_growth_r = 0
CO2_emission = 0

Model 1: restricted model
Model 2: E_ConsRenew ~ Low_CO2_elec + Pak_GDP + urban_growth_r + CO2_emission

  Res.Df    RSS Df Sum of Sq     F    Pr(>F)
1     35 909.09
2     31  42.92  4    866.17 156.4 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

By using coeftest(), individual significance test shows that Urban growth rate and low carbon electricity production are main predictors which support the hypothesis that these factors impact positively on consumption of renewable energy. The results suggest that 1 unit increase in low carbon electricity production results in significant increase in renewable energy consumption. Economic growth has a marginal impact on renewable energy consumption however, urbanization and carbon emissions have a significant positive effect on renewable energy. Thus, we accept the hypothesis, i.e., low carbon electricity production, urbanization and carbon emission as well as a marginal economic growth are significant for the electricity consumption from renewable sources.

### *8.4. Contribution to the literature*

The study shows the existing literature which gives empirical evidence that agrees with previous research shows the significance of energy consumption, industrial growth, urbanization and CO2 emissions on the economic growth of Pakistan (Abbasi et al., 2021) . (Ayinde et al., 2019) extends this work by showing the effect of economic growth, industrialization and urbanization on energy consumption in Nigeria.

However, in Pakistan, there is a literature gap related to specific dynamics, where sustainable consumption of energy from renewable resources is important for meeting the increasing demand of energy, rapid increase in the trends of urbanization, and policy making to provide people with clean and sustainable energy. The findings overall can inform stakeholders and policymakers in crafting more effective strategies to advance adoption of renewable energy in line with goals of international sustainability and necessary to achieve SDG7 by 2030.

## 9. Conclusion

The research explains the significant effect of urbanization and production of low carbon electricity in Pakistan on renewable energy consumption. The empirical result shows the robust positive relationship between the low carbon energy sources availability and increase in renewable resources adoption. The coefficient of low carbon electricity shows that each unit increase in low carbon electricity availability increases renewable energy consumption. Urbanization also considers as main determinant which suggests that expansion of urban areas provide a conductive environment for development of renewable energy infrastructure.

The statistical value of model shows F-statistics value of 156.4 and p-value< 2.2e-16 which reinforces that variables included are significant. Also, the model shows that Co2 and GDP emission do not have statistically significant impact, showing a weak relationship among renewable energy consumption and economic growth however, when applied with higher order terms, these variables become significant. This could be implied that there is need to prioritize investment in technologies of low carbon energy by government like wind power and solar.

This includes giving incentives for investment in private sector and reducing hurdles of bureaucratic for projects of renewable energy. The policies of urbanization must integrate solutions of renewable energy, and they need to promote initiative of smart city which incorporates sources of renewable energy into urban infrastructure like solar panels on wind turbines and public buildings in urban areas. The educational campaigns are implemented to increase the public awareness of renewable energy benefits which helps to drive public demand and renewable solutions acceptance. Supportive Regulatory Framework must be established which encourages the renewable energy transition. This might include creating favourable tariffs for producers of renewable energy and implementing mandatory purchase of renewable energy obligations for utilities.

## 10. Further Directions

The future analysis must explore:

- The future analysis could include intercountry analysis of the developing countries. Similar dynamics are analysed in different countries having different economic conditions and energy policies to find out the scalable and best practices solutions
- Time series analysis must be conducted to assess changes in technology, market dynamics and policy impact on consumption of renewable energy with time with causality analysis.

## 10.1. Ways to Address Limitations for Both Data and Model

- More granular data must be accessed like specific policies of government and patterns of regional energy consumption, could improve robustness and accuracy of model.
- Comparing the analysis with the countries who has worked toward improvement in their system and achieved the sustainable development goals.

## 11. Personal Reflection

The research work has deepened my complete understanding of intricate relationship among renewable energy consumption and economic factors. I have got valuable skills in regression modelling, statistical results interpretation and data analysis. I learnt the importance of planning and data collection because it can land you in a mud hole if the planning is not done right. My initial model was:
$GDP\ (Electricity\ Consumption) = \beta_0 + \beta_1(\text{GDP}) + \beta_2(\text{Urbanization Rate}) + \beta_3(\text{Industrial Supply}) + \beta_4(\text{Electricity Consumption}) + \epsilon$
But due to absence of quality data and non-significant model, I had to change the dynamics of the research multiple times and start over the research countless times.

## 11.1 Knowledge and/or Skills to Advance This Work (Future Directions)

Understand policies of energy and its implications would be helpful to better get empirical findings with recommendations for the stakeholder. By getting proficient in complex modelling methods help me to extract deeper insights and handle multifaceted datasets.

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