RENEWABLE ELECTRICITY GENERATION, ENERGY SECURITY AND LOW-CARBON TRANSITION IN PAKISTAN

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1. Research Framework

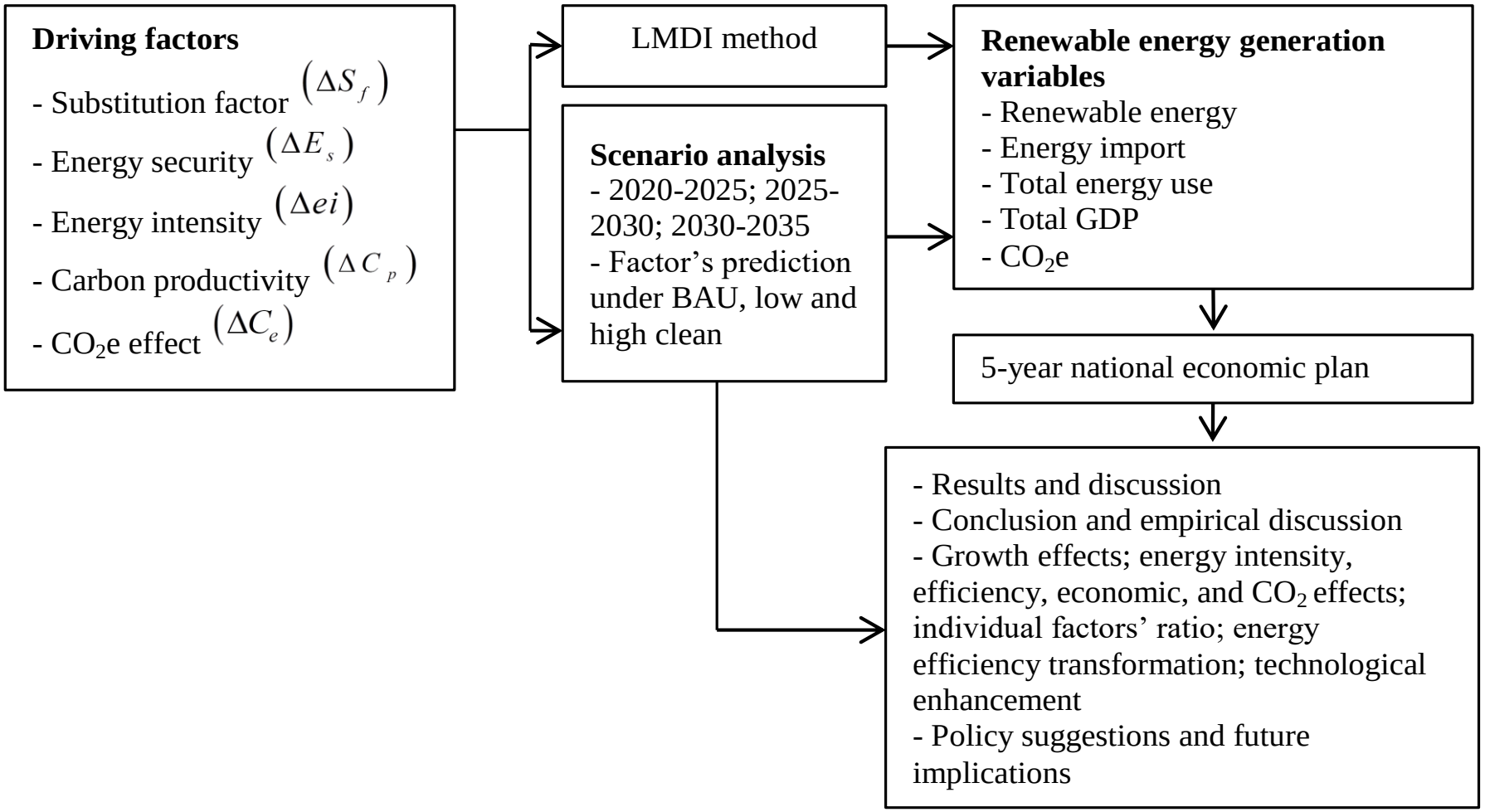
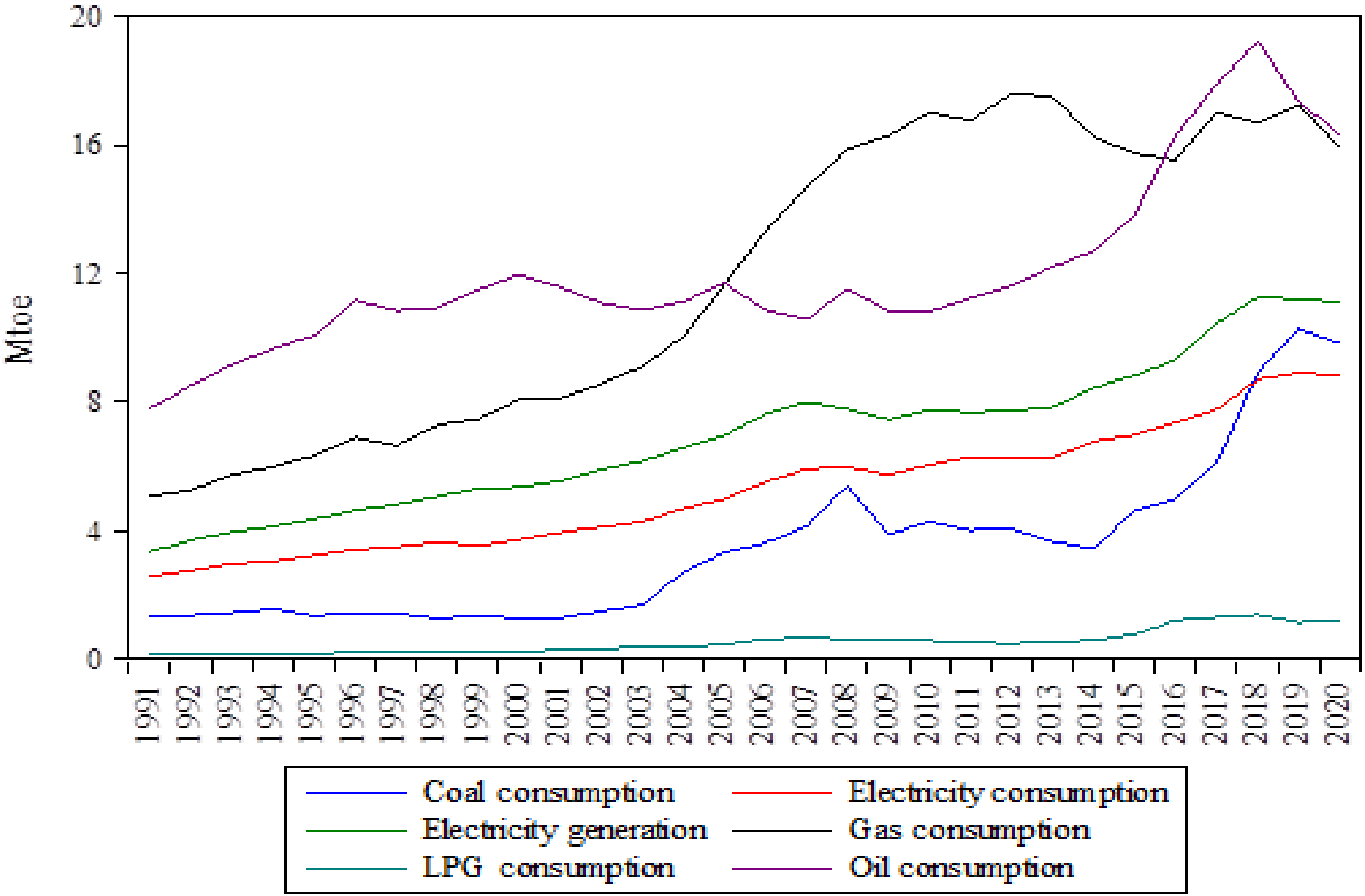
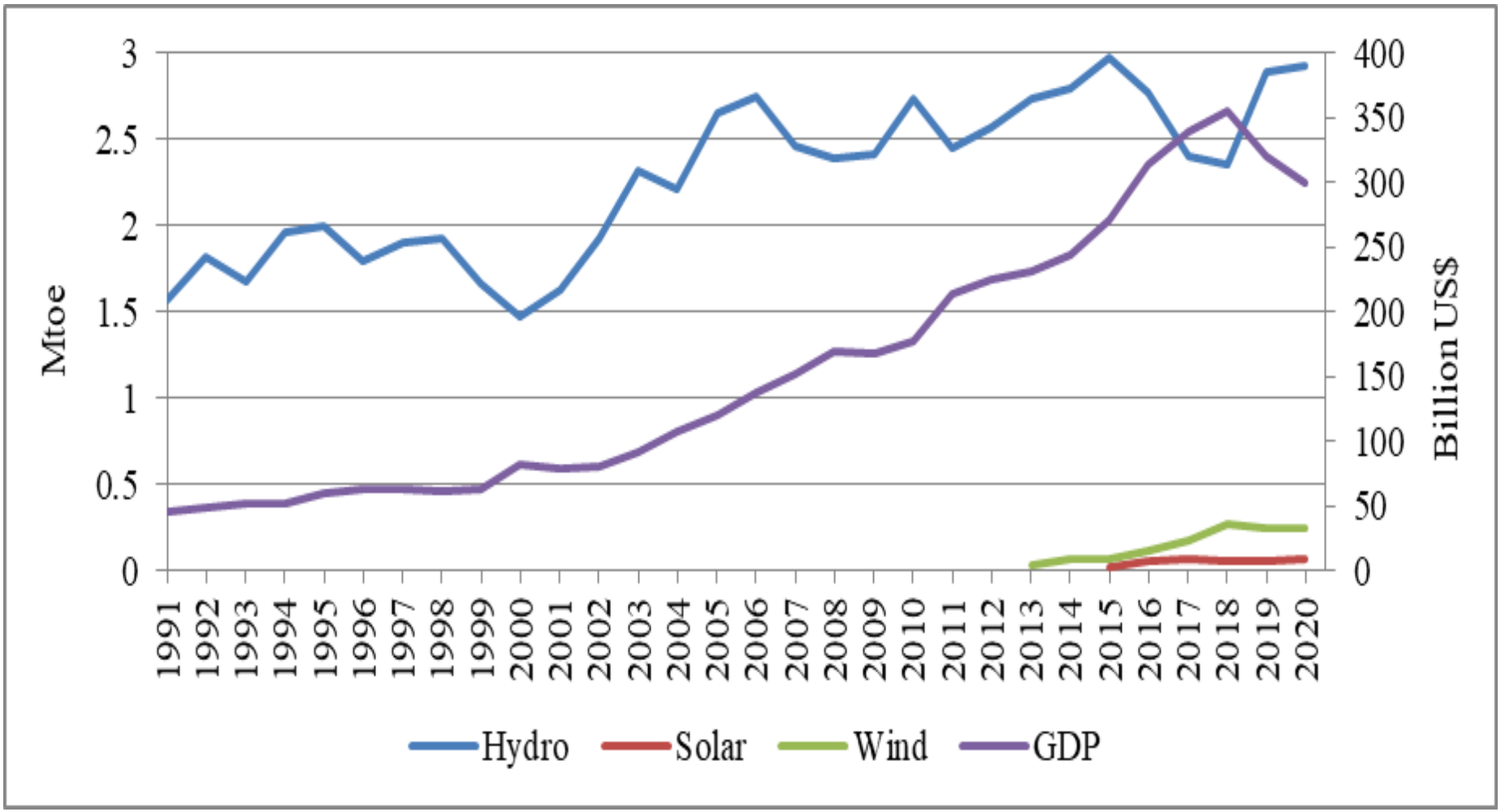


Fig. 1. Overview of the main factors and inputs considered in the LMDI model.
Source: the author.

2. Energy consumption and Electricity Generation



3. Renewable electricity generation and GDP



4. Motivation and Contribution

- More specifically from the ***Pakistani viewpoint***
- **Reg** might be the alternative to old-fashioned electricity sources (i.e., oil, coal and gas) for energy supply security and become a renewable energy source to confront the energy consumption security and electrification in the site area.
- **LMDI technique** to organize the main contributing factors that control and substitute the energy, environment and economic sustainability from the renewable electricity generation, which is completely different from past research.

- Fitting line and predicting outcomes from 2021-2035, the current research will provide scenario analysis and give policy recommendations under economic/social and renewable energy indicators.

Answer the Questions:

(i) What are the key factors adding to renewable electricity generation development in the past three decades in Pakistan?

(ii) What are the effects of each factor over the economic planning framework of Pakistan?

(iii) What are the long-term impacts of renewable electricity generation under the different economic and clean energy scenarios?

(iv) What are the impact of driving factors with the electricity, energy security, climate change, and technological innovation under the modern policy constraints?

DATA

Table 1
Description of main variables.

Variable	Abbreviation	Definition	Unit	Mean	S.D
Renewable electricity generation	Reg	Electricity generated is through hydro, wind and solar energy.	Mtoe	2.3225	0.5161
Energy import	Eip	Total energy imported from foreign.	Mtoe	20.1434	8.2766
Total energy consumption	Tec	All the energy consumption in the country.	Mtoe	33.2279	11.3259
Gross domestic product	GDP	Economic growth value addition.	Billion US$	156.3534	101.0762
CO_2 emissions	CO_2	Carbon dioxide emissions yearly effect.	Mt	116.8633	34.9268
Substitution factor	Sf	Renewable electricity generation per unit change in energy import.	Mtoe	0.1247	0.0302
Energy security	Es	Energy import per unit change in total energy consumption.	Mtoe	0.6012	0.0801
Energy intensity	Ei	Total energy consumption per unit change in total GDP.	Mtoe/Billion US$	0.2637	0.0871
Carbon productivity	Cp	It is the carbon productivity to the low carbon economy.	Billion US$/Mt	1.2125	0.4710

Methodology

$$\mathrm{Re}\,g^{t} = \frac{\mathrm{Re}\,g^{t}}{Eip^{t}} \cdot \frac{Eip^{t}}{Tec^{t}} \cdot \frac{Tec^{t}}{TGDP^{t}} \cdot \frac{TGDP^{t}}{CO_{2}^{\,t}} \cdot CO_{2}^{\,t}, \qquad (1)$$

$$= S_{f}^{\,t} \cdot E_{s}^{\,t} \cdot E_{i}^{\,t} \cdot C_{p}^{\,t} \cdot C_{e}^{\,t} \qquad (2)$$

Raza, M. Y., Wu, R., & Lin, B. (2023). A decoupling process of Pakistan's agriculture sector: Insights from energy and economic perspectives. *Energy*, *263*, 125658.

Raza, M. Y., & Lin, B. (2023). Future outlook and influencing factors analysis of natural gas consumption in Bangladesh: An economic and policy perspectives. *Energy Policy*, *173*, 113379.

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Empirical Results and Discussion

Table 2

Factor's decomposition contributions to renewable electricity generation (Mtoe).

Year	$\Delta \mathrm{Re}\, g^{t}_{S_f - effec}$	$\Delta \mathrm{Re}\, g^{t}_{E_s - effec}$	$\Delta \mathrm{Re}\, g^{t}_{E_i - effec}$	$\Delta \mathrm{Re}\, g^{t}_{C_p - effec}$	$\Delta \mathrm{Re}\, g^{t}_{C_e - effec}$	$\Delta \mathrm{Re}\, g^{t}_{total - effec}$
1991-1995	-18.67582	20.44826	-7.08636	-4.76921	36.87110	26.78796
1996-2000	-37.99843	8.91640	-17.74850	12.47130	14.34066	-20.01858
2001-2005	70.70681	-37.61155	-22.98192	30.08952	24.92854	65.13140
2006-2010	-20.75984	-3.15419	-21.31128	37.85477	6.59472	-0.77583
2011-2015	-18.44734	43.71227	-27.68324	16.41171	24.84723	38.84063
2016-2020	7.63076	-15.64880	35.72977	-8.07683	-0.35390	19.28099
1991-2020	-97.12655	38.27033	-111.62955	120.10380	156.18430	105.80233

Reg under economic and clean scenarios

Table 3

Renewable electricity consumption under various economic and clean scenarios.

			2025			2030			2035	
Indicators	Scenarios	LB	BAU	UB	LB	BAU	UB	LB	BAU	UB
Economic /social development indicators	$TGDP^t$ (billion US$)	384.747	386.004	387.261	458.715	460.081	461.447	525.037	526.495	527.952
	$CO_2{}^t$ emission (Mt)s	191.502	192.382	193.262	211.807	212.732	213.657	230.377	231.340	232.303
	Tec^t (Mtoe)	57.987	58.4778	58.9678	65.4210	65.9378	66.4547	71.939	72.4791	73.0185
	Eip^t (Mtoe)	36.741	37.129	37.517	42.778	43.201	43.624	48.866	49.312	49.758
	Scenarios	LC	BAU	HC	LC	BAU	HC	LC	BAU	HC
Renewable energy indicators	S_f (Mtoe)	0.039	0.089	0.139	0.026	0.076	0.126	0.006	0.055	0.106
	E_s (Mtoe)	0.569	0.619	0.669	0.602	0.652	0.702	0.652	0.701	0.652
$\mathrm{Re}\,g^t$ (Mtoe)		3.268	3.391	3.514	3.581	3.716	3.851	3.759	3.900	4.041

Results & Discussion

(i) electricity substitution, energy security and energy intensity make a major contribution to renewable electricity growth.

(ii) The Reg was estimated with increasing outcomes of carbon production and energy security, excluding 2016-2020 due to the COVID-19 epidemic situation. This shows that energy security and energy substitution have comparatively closer associations with cleaner energy, as compared to other factors, respectively.

(iii) The scenario forecasted that the average annual growth share of is forecasted about 1.24% from 2021-2035, which emphasizes that substitutability and energy security could be guaranteed by adapting ecological policies and technological progress.

(iv) The economic development indicators provide a rising and significant trend over the time, while the renewable electricity trends Sf and Es show favorable outcomes in respect of energy substitution and energy security.

Finally, Pakistan should attain sustainable growth and a robust synergy between **RETs** and energy security in the future.

Policy Suggestions

1. **RETs growth**

2. To accept these challenges, the government should make feasible costs and energy substitution, such as oil-gas, gas-coal and fossil fuel-renewable electricity in the latest framework. In respect of indigenous energy resources with low, clean and high quality, Pakistan holds world's 29th and 28th gas and coal reserves, which can be used for many years.

3. Global perspective low-carbon transitions:

4. For this, domestically low energy consuming devices, home appliances, and transport energy substitution can lessen CO_2 emissions and help in social development and energy security and diversify the primary energy demand.

5. Globally as well as domestically, it is suggested that RETs, control over energy import, subsidy, and use of natural resources can lessen pollution and energy intensity.

For example: Paris Agreement; CPEC, One Belt One Rod

Thank you