Renewable and Non-renewable Energy Potential of Central Asian States: An Analysis in Market Demand

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Abstract

Energy is one of the Central Asia's crucial resources and the region intends to accelerate and harness this potential, assigning it top priority in the developmental planning. The development of energy sector is expected to usher in enormous economic benefits, attract huge investments and strengthen bilateral and multilateral trade with improving regional cooperation. With the increase in renewable as well as non-renewable energy potential in Central Asian republics, the region aims not only to provide domestic energy at affordable cost, but also turn into net energy exporters in the near future which would have a positive impact on the global energy demand. In this backdrop, the present research paper has been buildup with the main aim to highlight that how and to what extent these republics can transform their economies with the proper management of their available resources particularly renewable and non-renewables. Moreover, the paper also examines the demand-supply mechanism which can help in regional integration and the benefits accrued thereof.

Key Words: *Energy Potential, Proven Reserves, Probable Reserves, Renewable, Non renewable, Market Demand, Demand-Supply Dynamics, Production Ratio, Energy Security, Surplus-Deficit Syndrome.*

Introduction

In the modern world, Energy has become one of the most basic of human needs. There is hardly any aspect of modern life that does not have the imprint of energy input, be it entertainment, recreation, agriculture, commerce, industry, transport, education, communication, health, architecture, etc.(Wani and Mir, 2015). Providing adequate and affordable energy is essential for eradicating poverty, improving human welfare, and raising living standards worldwide (Asif and Muneer, 2007). Without having sufficient energy resources "nations can neither initiate the process of economic growth and development nor sustain it for long" (Chandra, 2015). Energy is inevitable for human life and a secure and accessible supply of energy is crucial for the sustainability of modern societies. In fact as we trace the course of human civilization and its major accomplishments, they can largely be attributed to increasingly efficient and extensive harnessing of various forms of energy. With the growing world population and people's innate aspirations for improved life, a central and collective global issue in the new century will be sustaining economic growth within the constraints of our planet's limited resources (Asif and Muneer, 2007). As the very basis of development, energy use is closely related to the level of productivity in the industry, commerce, agriculture and even in office activities. Energy consumption per capita is one of the indicators or benchmarks for measuring the standard of living (Wani and Mir, 2015).

The realization of the importance of energy security has led academicians to study the supply demand scenario of energy sources all over the world so that that nations can develop and maintain sophisticated and appropriate technology to harness both renewable and non-renewable sources of energy. Energy, no doubt, has attained the status of a 'strategic commodity' and any uncertainty about its supply can threaten the functioning of the entire world (Wani and Mir, 2015). Although

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various policies and standards have been developed to provide energy production and consumption balance for the ever-growing population and ever-increasing energy consumption, the increase in energy consumption is superior to the increase in energy production. Therefore, each country is mobilized to use alternative energy sources in addition to fossil energy sources according to its geographical location and potential resources (Canbaz et al., 2021). The main issue with the dependence on non-renewable energy sources is their eventual depletion, as evident by Haider (2020), who studied total oil and gas reserves in the world and smart investments of Exploration and Production companies in renewable energy sources. The total oil in the world was reported in the range of 1.27, and 1.70 trillion barrels of oil (1.27 trillion (USGS), 1.64 trillion (IEA), and 1.7 trillion (BP statistical Review of World Energy) and the total world's gas reserve was reported 7490 trillion cubic feet in the study. The present reserves are estimated to stand for 40 to 45 years by considering daily oil consumption, which was 99.6 million barrels in 2018. Natural gas reserves are estimated to last for 50 to 55 years. However, the demand for the provision of energy is increasing worldwide and will continue to rise due to rapidly rising human population and modernisation trends across the world. In 2025, energy demand in the emerging economies is expected to exceed that of the mature market economies by 9%. Much of the growth in energy demand among the emerging economies is expected to occur in emerging Asian economies (Asif and Muneer, 2007).

The energy sector holds an important place in the economies of Asian region as it provides required fuel to the respective economies and surplus energy for export (Wani and Mir, 2015). However, from the energy research point of view, Central Asia has received less attention than other Asian regions (Mehta et al., 2021). Energy scarcity in Central Asia exists because of multiple dimensions including the geographical context, nature, environmental influence, and international factors. Despite its access to diverse energy resources (fossil and non-fossil), Central Asia is facing a complex energy security crisis (Mehta et al., 2021).However, Central Asia's energy resources are under tremendous strain due to its significant and ongoing economic growth. The governments of these nations must make significant efforts to increase energy supplies due to the widespread imbalance between supply and demand for energy sources. Given their consumption patterns, Central Asia may experience severe energy supply restrictions. The region's energy needs have been growing extremely rapidly. In this strategic perspective, achieving energy security is crucial for both their economic growth and their human development goals, which include reducing unemployment and poverty (Wani and Mir, 2015). Energy scarcity in Central Asia exists because of multiple dimensions including the geographical context, nature, environmental influence, and international factors. Despite its access to diverse energy resources (fossil and non-fossil), Central Asia is facing a complex energy security crisis [World Bank, 2019]. The provision of modern, affordable, and reliable energy services remains a challenge besides, its ample fossil fuel resources, Central Asia has a high potential for renewable energy, which can generate energy sustainably (Mehta et al., 2021). However, as pointed out by Laldjebaev et al.(2021), there are certain barriers to renewable energy development in Central Asian countries including regulatory framework, outdated and overloaded infrastructure, lack of financial resources and government support, high capital costs for new renewable energy equipment and insufficient expertise , date and awareness. However, these barriers are interrelated and require a systematic, cross-sectoral approach to effectively overcome them. The literature available is clear on the fact that central Asian countries are going to play a pivotal role in the supply and demand scenario of energy. However, a comprehensive and state-wise study needs to be conducted to ascertain how the region is faring when the demand of energy and its supply are considered. Energy surplus will be one the best currencies for any economy to have as the next quarter of the 21st century comes into existence. On the other hand, an energy deficit economy may face hardships and severe challenges ahead. In this context our paper tries to give a clear and concise snapshot of the current demand supply scenario of energy resources among the central Asian countries of Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan and Kyrgyzstan

Considering the above discourse one can easily glean the fact that energy is one of the Central Asia's crucial resources and the region should accelerate and harness this potential, assigning it top priority in the developmental planning. The development of energy sector is expected to usher in enormous economic benefits, attract huge investments and strengthen bilateral and multilateral trade with improving regional cooperation. With the increase in hydrocarbons and generation of renewables in Central Asian Republics, the region aims not only to provide domestic energy at affordable cost, but also turn into net energy exporters in the near future which would have a positive impact on the global energy demand. In this backdrop, the paper has been buildup with the main objective to highlight that how and to what extent these States can transform their economies with the proper management of their available resources, particularly, hydrocarbons and renewables. Moreover, the paper will examine the demand-supply mechanism which can help in regional integration and the benefits accrued thereof. However, Central Asian States are bestowed with gigantic sources of energy potential such as hydrocarbons like Oil & Natural Gas and hydropower etc. which are discussed herewith:

Hydrocarbon Potential

As a result of the energy wealth, Kazakhstan, Turkmenistan and Uzbekistan got a prominent space on the hydrocarbon map of the world. Kazakhstan has proven reserves estimated at 30 thousand million barrels (3.9 thousand million tons) of oil and proven natural gas reserves of 45.7 trillion cubic feet (1.3 trillion cubic meters), which constitutes 1.8% and 0.7% of global proven reserves with a reserve to production ratio (R/P) of 47.4 years and 82.5 years respectively (British Petroleum Statistical Review, 2022). These figures which are reproduced in the Table 1 and Table 2 are self-explanatory and reveal the status of CARs in these two important resources. Turkmenistan has proven reserves estimated at 0.6 thousand million barrels (0.1 thousand million tons) of oil and proven natural gas reserves of 618.1 trillion cubic feet (17.5 trillion cubic meters), which constitutes 0.05% and 07.2% of global proven reserves respectively (British Petroleum Statistical Review, 2024) with a reserve to production ratio (R/P) of 07.6 years and more than 230.7 years respectively.

Country	2002	2021	June 2024				
	Barrels	Barrels	Tones	Barrels	Growth Rate	World Share	R/P Ratio
Kazakhstan	5.4	30.0	3.9	30.0	82.0	1.80%	45.3
Turkmenistan	0.5	0.6	0.1	0.6	16.67	< 0.05%	07.6
Uzbekistan	0.6	0.6	0.1	0.6	0.00	< 0.05%	34.7
Tajikistan	0.012	0.012	0.001	0.012	0.00	< 0.001	…
Kyrgyzstan	0.04	0.04	0.005	0.04	0.00	< 0.0001	…
Total	6.5	31.2	4.1	31.2	13.3%	1.9%	87.6

Table 1: Proven Reserves of Oil (000 millions)
Source: British Petroleum Statistical Review of World Energy, June 2024, available at www.bp.com/statisticalreview.

Country	2002	2021	June 2024				
	Tcm	Tcm	Tcf	Tcm	Growth Rate	World Share	R/P Ratio
Kazakhstan	1.3	2.3	79.7	2.3	43.47%	**01.2%**	**71.2**
Turkmenistan	2.3	13.6	480.3	13.6	83.08%	**07.2%**	**230.7**
Uzbekistan	1.2	0.8	29.9	0.8	- 0.78%	**00.4%**	**18.0**
Tajikistan	0.005	0.005	0.2	0.005	0.00%	**< 0.002**	**…**
Kyrgyzstan	0.005	0.005	0.2	0.005	0.00%	**< 0.002**	**…**
Total	**2.8**	**19.9**	**703.5**	**20.11**	**17.08%**	**8.804%**	**319.9**

Table 2: Proven Reserves of Natural Gas (Trillion c^m/feet)
Source: British Petroleum Statistical Review of World Energy, June 2024, available at: www.bp.com/statisticalreview.

Uzbekistan has proven reserves estimated at 0.6 thousand million barrels (0.1 thousand million tons) of oil and proven natural gas reserves of 39.7 trillion cubic feet (1.1 trillion cubic meters),

which constitutes 0.05% and 0.6% of global proven reserves respectively(British Petroleum Statistical Review, 2024) with a reserve to production ratio (R/P) of 34.7 years of oil and 18.0 years of natural gas.

The overall picture of these three republics shows that the proven oil and gas reserves are 31.2 thousand million barrels (4.1 thousand million tons) and 664.9 trillion cubic feet (19.9 thousand cubic meters), which represents 1.9% and 8.804% of proven oil and gas reserves of the world respectively(British Petroleum Statistical Review, 2024). The total reserve to production ratio (R/P) of all the three republics stands at 87.6 years, 319.9 years respectively which accounts 407.5 years and in an average the mean life of proved hydrocarbon reserves of all these three republics is 135.83 years (Table 3) and represents 10.70% of world's share in hydrocarbon reserves (Figure 1).

Country	**R/P Ratio (Oil)**	**R/P Ratio (Natural Gas)**	**Total (R/P Ratio)**	**World Share (Oil)**	**World Share (Natural Gas)**
Kazakhstan	45.3	71..2	116.5	1.80	1.2
Turkmenistan	07.6	230.7	238.3	< 0.05	7.2
Uzbekistan	34.7	18.0	52.7	< 0.05	0.6
Total	87.6	319.9	407.5	1.9%	8.804%
Mean = 135.83 Years				**Total** = 10.70%	

Table 3: R/P Ratio and world share of Proven Hydrocarbon Reserves

Source: Calculation is based on the data given in various reports of British Petroleum Statistical Review of World Energy till June, 2024.

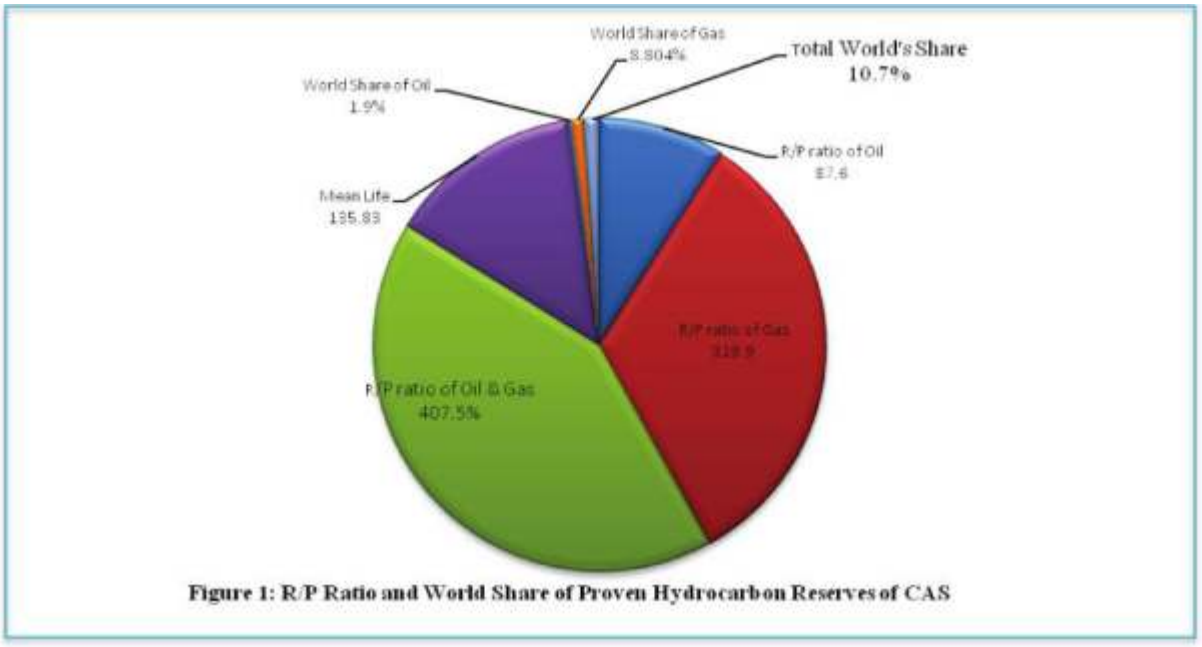


Figure 1: R/P Ratio and World Share of Proven Hydrocarbon Reserves of CAS

Hydropower Potential

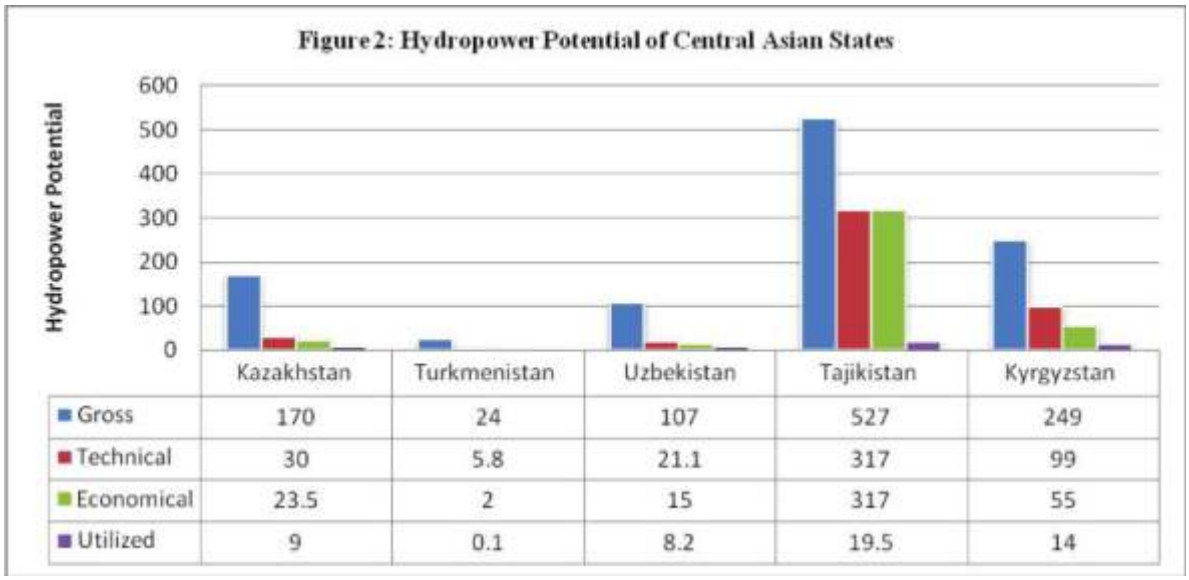
The gross hydropower potential of Kazakhstan is theoretically estimated 170 billion KWh of which 27 – 30 billion KWh is cost-effective and viable (technically potential) for use while 23.5 billion KWh is economically viable which constitutes 5.71% of Central Asian hydroelectricity share(Yasinskiy et al., 2013). The gross hydropower potential of Uzbekistan is 107 billion KWh of

which the technically potential hydropower resources is estimated at 21.1 billion KWh while 15 billion KWh is economically viable which constitutes 3.65% of total share of Central Asian electricity (Table 4). Turkmenistan has 24 billion KWh (The gross hydropower potential of 24 billion KWh constitutes 2.2 percent of total share of Central Asian hydroelectricity)of which the technically potential is 5.8 billion KWh while two (02) billion Kwh being economically viable which constitutes 0.48% of total share of Central Asian hydroelectricity (Table 4). Tajikistan and Kyrgyzstan are the other two republics of the region which are gifted by nature with large hydropower wealth.

Country	billion KWh/Annum							
	Gross		Technical		Economical		Utilized	
	Total	Share in CA (%)	Total	Share in CA (%)	Total	Share in CA (%)	Total	Share in CA (%)
Kazakhstan	170	15.8	30	6.3	23.5	5.71	9	17.7
Turkmenistan	24	2.2	5.8	1.2	2	0.48	0.1	0.18
Uzbekistan	107	10	21.1	4.5	15	3.65	8.2	16.12
Tajikistan	527	48.9	317	67.1	317	76.86	19.5	38.4
Kyrgyzstan	249	23.1	99	20.9	55	13.3	14	27.6
Total	**1077**	**100**	**472.9**	**100**	**412.5**	**100**	**50.8**	**100%**

Table 4: Hydropower Potential (Billion Kilowatt hours/Annum)

Source: United Nations Economic and Social Commission Organization and British Petroleum Statistical Review of World, 'Energy Review,' June 2022/available at: www.bp.com/statisticalreview.



Tajikistan possesses a total hydropower potential of 527 billion KWh, of which industrial (technical) hydro potential is 317.82 (60.3%) billion KWh and total potential of small hydropower potential is 184.46 (35.001%) billion KWh and 24.72 (4.69%) billion KWh is economically feasible

for construction per year respectively. Taking together all these potentials constitute 4% of global hydropower potential (Figure 2). Given the hydropower potential, it has been estimated that the republic of Tajikistan losses 401.0 million KWh in terms of heat annually (United Nations Economic and Social Commission for Asia and the Pacific, 2011). Since, hydropower is the main resource of the country, therefore it, requires an efficient power potential utilization for the sake of sustainable prosperity of the country. Kyrgyzstan possesses total hydropower potential of 249 billion KWh, of which industrial (technical) and economically hydro potential is 99 (39.75%) billion KWh and total potential of small hydropower potential is 150 (60.24%) billion KWh (United Nations Economic and Social Commission for Asia and the Pacific, 2011).These potentials constitute 2.01% of global hydropower potential (Figure 2).

Solar Power Potential

Central Asia possesses the gigantic renewable energy potential such as wind in Kazakhstan, Solar in Uzbekistan & Turkmenistan, water in Kyrgyzstan and Tajikistan, which remained largely untapped, could provide opportunities for increasing renewable energy uptake in these countries(KomilaNabiyeva, 2015).Due to its vast territory, almost two thirds of Central Asia's theoretical solar power potential lies in the chest of Kazakhstan (Table 5). However, Turkmenistan and Uzbekistan have significantly more intense solar irradiation, with the largest areas categorized as the highest possible levels, class 10 (Table 5). To date, there have been more solar than wind power developments in Central Asia. Kazakhstan leads on installed capacity, followed by Uzbekistan. Even with a photovoltaic (PV) solar conversion efficiency rate of less than10%, the total amount of solar irradiation received by the Central Asian countries is sufficient to generate 20 times more electricity than these countries currently generate.

Although, ranked eighth in the world in terms of hydropower, Tajikistan possess significant renewable energy resources in terms of hydropower, Solar, wind, biomass and geothermal which could have helped the country to feed its energy needs but due to the technological backwardness, thecountrycould utilize less than 4.0% of hydropower and <1% of other renewable energy potential(Tajikistan Energy Charter Secretariat, 2022).However, the theoretically and economically feasible renewable energy potential of Tajikistan has 410.1 × 10^9 kWh (410.1 Twh) of Solar (BahtiyorEshchanov& et. al., 2019), 527.0 Twh of gross theoretical Hydropower; 146.135 Gigawatt(GW) of Wind; 1614.14MW of Biomass (Express Analysis Tajikistan's (AET) Energy Sector); 0.045Mtce of Geothermal(Express Analysis Tajikistan's (AET) Energy Sector); 413.37 million tons of Coal (Express Analysis Tajikistan's (AET) Energy Sector).

Country	Class	kWh/m^2/day	kWh/year	TWh/year
Kazakhstan	7	3.5 – 4.0	989.6 × 10^9	989.6
	8	4.1 - 4.5	3723.8 × 10^9	3,723.80
	9	4.6 – 5.0	1875.1 × 10^9	1,875.10
	10	5.1 - 5.5	95.2 × 10^9	95.2
	11	5.6 – 6.0	0.6 × 10^9	0.6
Total			6684.3 × 10^9	6684.3
Kyrgyzstan	8	4.1 - 4.5	54.6 × 10^9	54.6
	9	4.6 – 5.0	268.4 × 10^9	268.4
	10	5.1 - 5.5	210.9 × 10^9	210.9
	11	5.6 – 6.0	3.4 × 10^9	3.4
Total			537.3 × 10^9	537.3
Tajikistan	9	4.5 - 5.0	124.9 × 10^9	124.9
	10	5.0 - 5.5	200.7 × 10^9	200.7
	11	5.5 - 6.0	84.2 × 10^9	84.2
	12	6.0 - 6.5	0.4 × 10^9	0.4
Total			410.1 × 10^9	410.1

Uzbekistan	8	4.0 - 4.5	35.4×10^9	35.4
	9	4.6 - 5.0	916.1×10^9	916.1
	10	5.1 - 5.5	243.5×10^9	243.5
Total			1195.0×10^9	1195
Turkmenistan	8	4.0- 4.5	50.2×10^9	50.2
	9	4.6 - 5.0	791.5×10^9	791.5
	10	5.1 - 5.5	642.0×10^9	642
Total			1483.7×10^9	1483.7

Table 5: Theoretical Solar Power Potential of Central Asia States at different Classes
Source:http://osce-academy.net/en/research/cadgat.

***Note**: The data represents the total potential of solar energy per year as a function of land area per solar class (KWh/m²/day). Each solar class correlates to a specific 0.5 kWh/m²/day range. Energy is calculated by multiplying the productive land by the class, conversion efficiency and number of days per year. In this case, a standard calendar year of 365 days was used. The conversion efficiency rate applied was 10%.*

Kyrgyzstan, a poorest country in the region, has large renewable energy resource potential which remained untapped. The country has estimated 537.3×10^9 kWh(537.3 TWh) of Solar, 255.663Gigawatt(GW) of Wind[6], 200 megawatts of Biomass (In the Kyrgyz Republic, biomass as a source of renewable energy has considerable potential. Biomass processing, comprising animal and plant waste, as well as other organic material, results in production of 1, 61 billion cubic metre of combustible methane gas per year)and 163.0 Twh of gross theoretical[7]hydropower (Ministry of Energy of the Kyrgyz Republic, 2010).

Coal Potential

Central Asian States have also bestowed with coal reserves especially the States of Kazakhstan and Uzbekistan. Kazakhstan has 25,605 tons of proved coal reserves which represent the 2.4% of world's coal share and 226 years of life whereas Uzbekistan has 1,375 tons of proven coal reserves which represent 0.1% of world's coal share and 333 years of life. Therefore, while taking together the R/P ratios of both, the life of coal could be 559 years of life (Table 6).

Country	June, 2022			June, 2022		
	Tones	R/P Ratio	World Share	(Exajoules)		Balance
				Supply	Demand	
Kazakhstan	25605	**226**	2.4%	2.04	1.64	**0.4**
Turkmenistan	-	-		-	-	-
Uzbekistan	1375	**333**	0.1%	0.05	0.10	**-0.05**
Tajikistan	0.001	-	-	-	-	-
Kyrgyzstan	0.005	-	-	-	-	-
Total	**26980.006**	**559**	**2.5%**	**2.09**	**1.74**	**0.35**

Table 6: Proved Coal Reserves in Million tons

However, if India would have invested in the coal fields of Central Asian States especially Uzbekistan given the R/P ratio of coal, India won't had to face the coal crises situation during the Russia-Ukraine war in 2022.

Wind Power Potential

In addition to abundant fossil fuel and hydropower resources, the Central Asian countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan have vast amounts of other renewable energy sources. Among these, wind energy has the greatest potential for exploitation.

Due to its vast territory, almost three quarters of the theoretical wind power potential in Central Asia belongs to Kazakhstan. Nonetheless, Uzbekistan's wind power potential is ten times greater than its currently installed electricity generation capacity. Kyrgyzstan, Tajikistan and Turkmenistan's theoretical capacity of wind power is higher than their solar power and hydropower potential (Table 7).

Countries	**Capacity factor** / *Distance from the shore (miles)*	**0 - 0.18**	**0.18 - 0.22**	**0.22 - 0.26**	**0.26 - 0.3**	**0.3 - 0.38**	**Total**
Kazakhstan	*0-50 miles*	216.745	298.633	686.646	823.191	68.936	**2094.15**
	50-100 miles	443.727	681.356	1502.915	1316.112	35.376	**3979.486**
	100-5000 miles	128.651	498.109	3974.696	710.938	1.671	**5314.064**
G. Total							**11387.7**
Kyrgyzstan	*0-50 miles*	89.121	33.224	57.05	19.172	0.428	198.995
	50-100 miles	14.908	13.711	15.379	11.903	0.768	56.669
	100-5000 miles	0	0	0	0	0	0
G. Total							**255.663**
Tajikistan	*0-50 miles*	104.23	17.21	5.433	0.043	0	126.915
	50-100 miles	0.637	7.197	3.509	2.009	4.988	18.34
	100-5000 miles	0	0.152	0.585	0.145	0	0.881
G. Total							**146.135**
Turkmenistan	*0-50 miles*	183.517	400.382	15.864	0	0	599.762
	50-100 miles	311.135	647.288	47.49	0.279	0	1006.191
	100-5000 miles	1.427	331.878	52.61	0	0	385.914
G. Total							**1991.867**
Uzbekistan	*0-50 miles*	139.353	444.335	31.288	0	0	614.975
	50-100 miles	44.734	499.43	52.887	0.662	0	597.712
	100-5000 miles	11.966	298.209	150.339	12.078	0	472.591
G. Total							**1685.278**

Table 7:Wind Power Potential of Central Asian Countries (in GW)

Note: This table contains global onshore wind supply capacity based on a resource assessment performed at the National Renewable Energy Laboratory (NREL) based on the National Center for Atmospheric Research's (NCAR) Climate Four Dimensional Data Assimilation (CFDDA) mesoscale climate database.

Bio-energy Potential

In Kazakhstan, bio-energy potential was estimated at 300 MW while electricity generation potential from bio-energy was 35,000 GWh/year and heat generation potential is 44 million Gcal per year (Energy Charter Treaty, 2022). Another estimate is 2,328,920 GWh/year from conversion of timber waste, straw of cereal crops, cattle waste and sewage. With a large agricultural sector but only 10% of agricultural residue utilized, there is a lot of untapped potential for bio-energy. Agricultural waste has a potential capacity to produce up to 35 billion kWh of power and 44 million Gcal of heat. In Tajikistan, bio-energy potential was estimated at 300 MW and bio-energy sources can potentially produce almost 2000 GWh/year of electricity. The highest bio-energy potential was estimated in Uzbekistan at 800 MW with the annual potential of 1496 GWh, and up to 6 billion m^3 of bio-methane. Owing to production of cotton, and availability of over 3 million tons of cotton stalks per year, the gross bio-energy potential was estimated at 27,000 GWh/year and its technical potential at 2000 GWh/year (from glucose and reducing sugars or bio-ethanol). For biogas produced from livestock breeding and poultry farming, municipal sewage and other organic wastes, the technical potential was estimated at 8.9 million m^3 or 55.2 GWh per year. For Turkmenistan, information

about bio-energy potential was not available(United Nations Industrial Development Organisation (UNIDO) and ICSHP, 2022). In Kyrgyzstan, bio-energy potential was estimated at 200 MW 1300 GWh or 1.6 billion m^3 of biogas(United Nations Industrial Development Organisation (UNIDO) and ICSHP, 2022). Other sources estimate the potential at 53 PJ or 14,722 GWh. The agricultural biomass potential is estimated at 9732 TJ (terajoules) per year) and energy from forests and waste from wood processing industry is 2292 TJ/year.

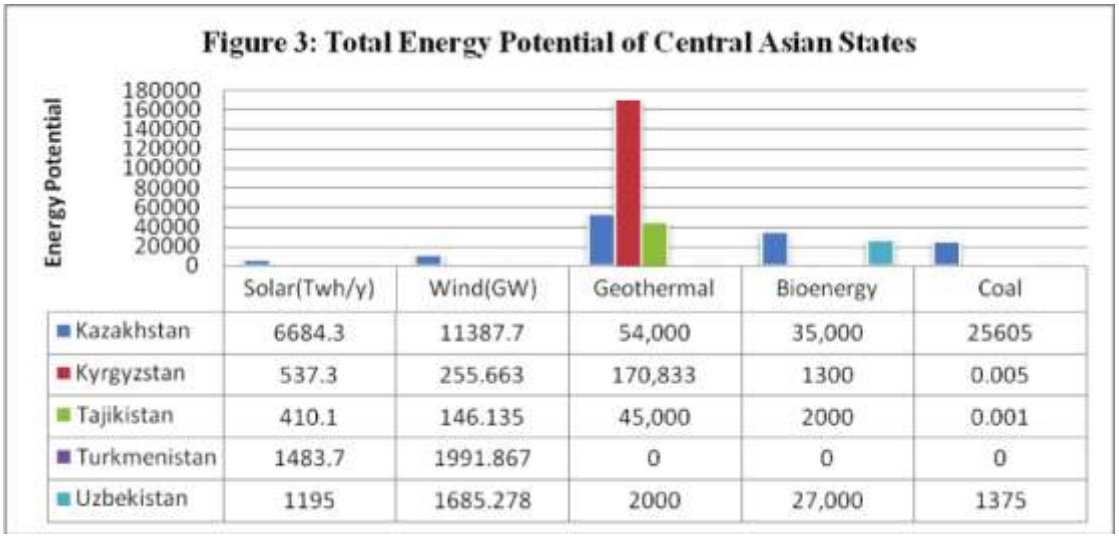
Geothermal Potential

In Kazakhstan, the estimated gross potential for geothermal energy is 54,000 TWh, technical potential is 54 TWh and economic potential is 0.54 TWh per year. In Kyrgyzstan, the geothermal sources canpotentially yield 615PJ (170,833 GWh).In Tajikistan, sources indicate that thegeothermal energy can potentially produce 45,000 GWh of powerannually. While information is not available for geothermal energy for Turkmenistan and in Uzbekistan, the grosspotential of geothermal energy was estimated at 2000 GWh/year (British Petroleum Statistical Review of World Energy, 2022). From the above calculations, it has been concluded that Central Asian States have 10310.4 Terawatt hours (Twh) of Solar, 15466.643 Gigawatt hours (Gwh) of Wind 271833 Terawatt hours (Twh) of Geothermal, 65, 300 Gigawatt hours (Gwh) of Bio-energy and 26980 tons of Coal potential (Table 8).

(Solar & Geothermal: Twh/y, Wind & Bio-energy: Gwh, Coal: Million tons)

Countries	Solar	Wind	Geothermal	Bio-energy	Coal
Kazakhstan	6684.3	11387.7	54,000	35,000	25605
Kyrgyzstan	537.3	255.663	170,833	1300	0.005
Tajikistan	410.1	146.135	45,000	2000	0.001
Turkmenistan	1483.7	1991.867	NA	NA	NA
Uzbekistan	1195	1685.278	2000	27,000	1375
Total	**10310.4**	**15466.643**	**271,833**	**65,300**	**26980**

Table 8: Total Energy Potential of Central Asian States
Source: Based on the author's calculation from the different sources



Supply of Energy Resources

In terms of hydrocarbon supply, Kazakhstan stands at 1728 thousand barrels (81.3 million tons) of oil and 19.7 billion cubic meters of natural gas (17.7 million tons of oil equivalent) which constitutes 2.53 % and 0.6 % of global oil and gas supply. Turkmenistan with 222 thousand barrels (11.0 million tons) of oil and 64.4 billion cubic meters of natural gas (57.9 million tons of oil equivalent), which constitutes 0.32 % and 1.91 % of global oil and natural gas production. Uzbekistan has 68 thousand barrels (3.2 million tons) of oil and 56.9 billion cubic meters of natural

gas (51.2 million tons of oil equivalent) which represents 0.1% and 1.7% of global oil and natural gas supply per day.Taking these three republics together, the sub-region has 2,018 thousand barrels (95.5 million tons) of oil and 141 billion cubic meters (126.8 million tons of oil equivalent) of natural gas production which constitutes 2.96% and 4.2% of global oil and natural gas production. In terms of hydropower supply, Kazakhstan has 0.67 mtoe, Turkmenistan has 0.01 mtoe, and Uzbekistan has 0.87 mtoe. Tajikistan possesses 1.38 mtoe and Kyrgyzstan has 1.22 mtoe (Figure 3). The total picture of these republics shows that they have 4.14 million tons of oil equivalent hydropower supply (The data has been calculated and converted from KWh to mtoe from the World Bank sources,2022).

Demand for Energy Resources

In terms of hydrocarbon demand, Kazakhstan has been consuming 265 thousand barrels (12.8 million tons) of oil and 9.5 billion cubic meters (8.5 million tones oil equivalent) of natural gas which constitutes 0.3% and 0.5% of global hydrocarbon demand per day (IEA Report of 2013). Turkmenistan is consuming 100 thousand barrels (4.8 million tons) of oil and 23.3 billion cubic meters (20.9 million tons of oil equivalents) of natural gas which constitutes 0.1% and 0.7% of global hydrocarbon demand per day respectively. Uzbekistan is consuming 82 thousand barrels (3.9 million tons) of oil and 47.9 billion cubic meters (43.1 million tons of oil equivalents) of natural gas which constitutes 0.1% and 1.4% of global hydrocarbon demand per day respectively. The three republics have 447 thousand barrels (21.5 million tons) of oil and 80.7 billion cubic meters (72.5 million tons of oil equivalent) of natural gas which constitutes 0.5% and 2.4% of global hydrocarbon demand per day respectively. In terms of hydroelectricity, Kazakhstan's demand has been 6.97 million tons of oil equivalent, Turkmenistan has 1.08 million tons of oil equivalent, Uzbekistan 4.11 million tons of oil equivalent. Tajikistan's 1.17 mtoe and Kyrgyzstan's 0.78 mtoe constituting respective figures of 2.9%, 0.5%, 2.3%, 1.02% and 0.05% of the global hydroelectricity consumption. Taking as a whole, the total hydroelectricity consumption is 14.11million tons of oil equivalent which constitutes 3.55 % of global hydroelectricity consumption per day.

Demand – Supply Dynamics of Energy Resources

The total demand – supply gap of all the Central Asian republics in oil has been 1535.78 thousand barrels in June 2022 with an annual growth rate of 4.49% from 2011 to June 2022, in which Kazakhstan has the potential to export 1498 thousand barrels with an annual growth rate of 5.2% and Turkmenistan 94 thousand barrels with an annual growth rate of -0.73%; but all other three republics namely Uzbekistan, Tajikistan and Kyrgyzstan have been importing oil resources from other two republics such as Turkmenistan and Kazakhstan.

The total demand – supply natural gap of all the Central Asian republics in natural gas has been 35.68 billion cubic meters in June 2022 with an annual growth rate of -7.19% from 2002 to June 2022, in which Kazakhstan has the potential to export 7.1billion cubic meters with an annual growth rate of 29.54% and Turkmenistan 40 billion cubic meters with an annual growth rate of 1.07% and Uzbekistan10.0 billion cubic meters with an annual growth rate of 23.02%. But other two republics, namely, Tajikistan and Kyrgyzstan have been importing natural gas resources from Turkmenistan, Kazakhstan and Uzbekistan. In case of hydropower consumption except Tajikistan and Kyrgyzstan, other three countries have been depicting hydropower deficit.

Thus, the total hydropower deficit of all the Central Asian republics has been estimated at 10.2 million tons of oil equivalent in June 2022 with an annual growth rate of -2.95% from 2014 to June 2022, in which Kazakhstan has the deficit of -6.4 mtoe with an annual growth rate of -4.85% and Turkmenistan -1.09 mtoe with an annual growth rate of -4.06% and Uzbekistan -3.51 mtoe with an annual growth rate of -0.50% but other two republics, namely, Tajikistan and Kyrgyzstan have been exporting hydropower at 0.20 mtoe and 0.57 mtoe with an annual growth rate of 4.70% and 5.94%. A consolidated picture of demand-supply gap of hydrocarbons and hydropower within CARs from 2002 to 2022, as reproduced in Table 9, shows some interesting equations and inferences.

(Oil: 000 barrels, Gas: billion m^3, Hydropower: million tons oil equivalent)

Country	Resource	2002	2014	2022	AAGR (2014-2022)
Kazakhstan	Oil	852	1220	1948	5.2%
	Gas	0.4	5.8	7.1	29.54%
	Hydropower	-3.78	-5.27	-6.4	-4.85%
Turkmenistan	Oil	102	104	94	-0.73%
	Gas	35.5	44.1	40	1.07%
	Hydropower	-0.7	-0.94	-1.09	-4.06%
Uzbekistan	Oil	22	10	-7	-9.79%
	Gas	1	13.2	10	23.02%
	Hydropower	-3.32	-3.28	-3.51	-0.5
Tajikistan	Oil	-25.09	-39.32	-14.48	-4.82%
	Gas	-50.2	-44.06	-6.64	-16.64%
	Hydropower	0.12	0.22	0.2	4.7%
Kyrgyzstan	Oil	-8.5	-13.36	-34.74	-13.5%
	Gas	-70.8	-26.76	-14.78	-13.15%
	Hydropower	0.3	0.41	0.57	5.94%
Total (Oil)		**942.41**	**1281.3**	**1535.78**	**4.49%**
Total (Natural Gas)		**-84.1**	**-7.72**	**35.68**	**-7.19%**
Total (Hydropower)		**-7.38**	**-8.86**	**-10.2**	**-2.95%**

Table 9: Demand-Supply Dynamics (DSD) of Energy Resources
Source: Calculations based upon various relevant sources

Summary and Conclusion

On the basis of calculations, the total primary energy (primary energy comprises commercially traded fuels which including modern renewable sources) demand in Kazakhstan, Turkmenistan and Uzbekistan has58.1 million tons (comprised of 12.8 million tons of oil, 8.5 million tons oil equivalent of natural gas, 35 million tons of coal and 6.97 million tons of oil equivalent electricity), 34.0 million tons and 50.5 million tons of oil equivalent respectively. On per capita basis, the total primary energy demand of these republics on an average has been 2.2 tons of oil equivalent which stands higher as compared to world energy demand of 1.8 tons of oil equivalent, meaning, thereby, that the compound average annual growth rate of energy demand was estimated to increase by 1.7% in 2035(IEA, 2013). It indicates that these republics are energy intensive republics and would result in the production of the highest share of carbon emissions that estimated at 1.4%, 1.6% and 1.2%, in Kazakhstan, Turkmenistan and Uzbekistan respectively. The issue of energy resources in the Central Asian States as well as in world is of very crucial concern. Thus, taking together both the reserve to production ratio (R/P) and energy consumption, the Co_2 emissions of the Central Asian States, there is a need to rethink about the life of hydrocarbon reserves for their management, otherwise the region will face the energy crunch in the near future. Because of the global demand(Valentina Kasymova, 2011)for hydrocarbonswhich is increasing very fast that will lead to decrease in the reserve to production ratio (R/P) from the present mean life of 135.83 years of their reserve base and at the same time these States are energy intensive economies as is evident from their energy demand pattern with respect to the world benchmark. However, keeping in view their proven oil and natural gas reserves, the three hydrocarbon resource – rich States of Central Asia has

no alternative, but to bring efficiency in energy consumption in order to save their economies and to go for alternative renewable options.

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