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Review

Non-Hydropower Renewable Energy in Central Asia: Assessment of Deployment Status and Analysis of Underlying Factors

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Abstract: Despite globally progressing energy transition, the deployment of non-hydropower renewable energy (NHRE) in Central Asia is moderate and varies by country. This paper aims to explain why Central Asian countries with significant challenges in the energy sector are least engaged in NHRE development. In doing so, the paper first reviews scholarly work on renewable energy (RE) deployment in developing countries. For assessing the NHRE development status in Central Asian countries, the paper adopts a two-stage analytical framework. First, it assesses the current situation in these states' energy sectors in connection to their economic growth and development, environmental sustainability and energy security. Then, it analyses the preparedness of the national energy sectors for NHRE diffusion in six dimensions: structure of energy sector, RE regulation, institutions and governance, capital and investment, infrastructure and business environment, and human capital. Based on the results of the two-stage analysis, the paper argues that more advanced economically and institutionally countries are more likely to commence NHRE development.

Keywords: central Asia; non-hydropower renewable energy; renewable energy policy

1. Introduction

The term "renewable energy" (renewables), according to the International Renewable Energy Agency (IRENA), embraces hydro- and geothermal power, bioenergy, as well as ocean, solar, and wind energy (while small-scale hydropower (SSHP) is considered to be aligned with the concept of renewable energy, the inclusion of large-scale hydropower (LSHPP) in the category of renewables is debated). Historically, the nations were predominantly harnessing hydropower potential, for it was comparatively inexpensive and abundant [1]. Such virtues of hydropower have been especially significant for developing economies, including those in Central Asia, helping them to solve the problems of energy shortage, poverty, and inequality [2–4]. Partially because hydropower revealed some features inconsistent with sustainability [1], the improvement of commercial viability of non-hydropower renewable energy (NHRE) sources [5–7] has transformed the latter in a feasible alternative to hydropower [8]. The deployment of NHRE is uneven [9], with developed economies leading in the sector. The rationales behind the nations' renewables strategies naturally vary. Even fossil-fuel rich nations are increasingly motivated to develop renewables as one of the ways to enhance their innovative capabilities and sustainability [10,11]. Although energy-resource poor developing economies are less competent of employing renewables for the lack of domestic innovative and financing potential, they gradually incorporate NHRE solutions [12,13] helping them progress towards the attainment of the Sustainable Development Goals (SDG) [14,15].

This paper examines the case of NHRE diffusion in Central Asian countries. Kazakhstan, the most prosperous economy (categorized internationally as an upper-middle-income country), relies heavily on hydrocarbon resources and commodities markets. Kyrgyzstan is a lower-middle-income country, the second poorest after Tajikistan and the least urbanized economy in the region. Remittances account for 33.2% of Kyrgyzstan's GDP. Tajikistan is a low-income economy with a predominantly rural population (the urbanization rate is 27%). Over 45% of Tajikistan's population is under the age of 20. The lack of domestic employment opportunities results in massive labor emigration and subsequent remittances dependency equal to about one-third of GDP. Like Kyrgyzstan, Tajikistan is vulnerable to the effects of climate change, due to rapidly melting glaciers. Turkmenistan is an upper-middle-income country with the second-highest GDP per capita in Central Asia. More than 90% of Turkmenistan's export is made up by mineral products (primarily gas), and over 90% of exports are China-oriented. Uzbekistan is a lower-middle-income economy and the most populous country in Central Asia. Uzbekistan is also vulnerable to climate change effects, as the rising average temperatures accelerate the problem of water deficit [16].

The existing literature on renewables (RE) deployment in Central Asia either concentrates on one country [17–21] or addresses RE indirectly, examining the nexus linkages [22–26]. Moreover, the geographic focus and issue coverage in Central Asian RE research is uneven. Overall, Kazakhstan is studied more comprehensively, with a greater variety of RE sources examined [27–29]. RE research on Tajikistan [30–33] and Kyrgyzstan [34,35] are mainly linked to large-scale hydropower plants (LSHPP) and water-energy nexus. While Uzbekistan's risen economic openness and newly endorsed orientation at RE deployment motivate growing scholarly interest to the country [36], studies devoted to Turkmenistan remain scarce [37]. In 2019, several brief data summaries on RE in Central Asian countries were published; they are compiled upon the publicly open sources and presented in a purely technical format [38–41].

This study bridges the existing gaps in scholarly work on RE development in Central Asia in several respects. First, it undertakes a comprehensive overview of the NHRE advancement in each Central Asian economy. Second, it examines the development of NHRE in Central Asian countries upon a two-stage analytical framework: analysis of national energy systems' efficiency; and analysis of national energy systems' readiness for RE diffusion. Third, the study incorporates a diverse range of sources. Besides internationally published data and scholarly work, this study draws upon policy documents, national and local media, as well as knowledge gained from personal communications with the respective countries' policymakers, regulators and experts during the workshops on renewable energy development in Central Asian economies organised by the ADB and CAREC Institute in 2018 in Baku and in 2019 in Almaty.

Building upon the existing research on the determinants of RE development, this study critically analyzes the case of NHRE deployment in Central Asia. This paper examines the hypothesis that more advanced economically and institutionally Central Asian countries demonstrate greater engagement in NHRE deployment. The rest of the paper is organized into five sections. The following section overviews RE research, with a particular focus on studies examining the factors behind NHRE deployment in developing economies. It also organizes relevant concepts, presents the methodological framework and describes data sources. Section 3 characterizes the performance of Central Asian national energy systems. Section 4 analyses factors determining the deployment of NHRE in Central Asian economies. Section 5 discusses principal findings and draws policy recommendations. Section 6 summarizes the arguments.

2. NHRE Deployment in Developing Countries: Empirical Evidence, Methodology and Data

2.1. Literature Review

To frame our analysis of the determinants facilitating and impeding NHRE deployment in Central Asia, we first present a succinct review of the existing research on developing countries. Bourcet [12] notes that there are differences between the factors affecting the deployment of RE in developed and developing economies and summarizes that majority of studies prove positive effect of the population size, RE policies, and participation in the Kyoto Protocol. In turn, the negative impact on RE diffusion is observed for traditional energy industries lobby. Income level, CO_2 emissions, energy security, financial sector development and institutional quality are found to have an ambiguous influence. Studying the determinants of NHRE diversification in 117 developing countries over the period 1980–2011, Seriño [13] shows that higher levels of per capita income, technological innovation, human capital, dependence on imported energy, and crude oil price, as well as the implementation of RE policies, promote diversification. Examining 108 developing countries between 1980 and 2010, Pohl and Mulder [42] find that NHRE diffusion accelerates with the implementation of economic and regulatory instruments, higher per capita income and better schooling levels, as well as with stable democratic regimes. Increasing trade intensity, higher levels of foreign direct investment (FDI) and official development assistance (ODA), institutional and strategic policy support programs, and rapid growth in electricity consumption delay the diffusion of NHRE. Seriño [13] and Pohl and Muilder [42] agree that the abundance of hydropower and availability of fossil-fuel resources impede diversification. Pohl and Muilder [42] identify no evidence for any influence of the level of the financial sector development and weak evidence of a positive influence of the Kyoto Protocol on NHRE diffusion. Confirming findings for the financial sector, Seriño [13] claims robust evidence of the Kyoto Protocol positive influence on NHRE diversification.

Regarding economic openness, Amri [43] reports the bidirectional link between RE development and economic openness, which is critical for technology transfer and diffusion. This aspect is relevant to Kazakhstan and Kyrgyzstan, the members of the Eurasian Economic Union (together with Armenia, Belarus and Russia). Kazakhstan has been benefiting from the Eurasian Development Bank (EDB) financing and Russia's investments in RE projects [44,45]. Importantly, Yao et al. [46] finds that compared to developed economies, the developing countries reach the turning point on the U-shaped renewable energy Kuznets curve at a lower income level. Seriño [13] also demonstrates the diversification of NHRE as developing countries grow more affluent. This may be linked to the effects of technology transfer and learning-by-doing, but also to gradual reforms in still heavily subsidized or even free of charge electricity (as used to be in Turkmenistan through the year 2019) domestic electricity sectors. Bahrami et al. [37], for instance, argue that in Turkmenistan, the LCOE for wind (0.0435 to 0.0893 USD/kWh) opens up large exporting opportunities. For low and lower-middle-income economies, NHRE is often seen as a plausible solution for energy cut-offs and blackouts, especially in rural areas. Eshchanov et al. [18] (p. 796) assess that, in Uzbekistan, "any need for renewable energy sources at the present time exists mainly due to the cut-offs or shortages in the traditional energy supply".

NHRE deployment in developing economies with modest own means may create greater risks of new kinds of dependencies on critical materials, foreign technology, and financial resources [47–50]. Greater deployment of RE may also intensify the risks of political dependency on a key donor of financial or technological resources, or the risks of geopolitical conflicts stirred by the complexity of resource-sharing [51,52].

Studying the impacts of renewables-related development aid, Marquardt [53] distinguishes between the effects of negative fragmentation for the local-scale projects and positive pluralism for the national level projects. Marquardt et al. [54] observe that while ODA provides expertise and financial capacity for the enhancement of energy transitions in developing countries, the aid is often loosely linked to the recipients' goals and challenges for renewables. Marquardt [55] claims that ODA cannot force energy transition, but can become a driving force for creating niches for technological experiments and policy innovations. Scaling up the niche level developments into full-fledged energy

transitions is more successful when the donor considers the recipient's domestic policy priorities and complex interlinkages within macro-societal structures [56,57]. Yet, Kim [58,59] holds that donors' energy aid-giving patterns changed after the adoption of the Kyoto Protocol, and now their aid decisions are influenced by the recipient energy needs aligned with the SDG. Delina [59], Buntaine and Pizer [60] and Kim [58] argue that by trying to meet the donors' financing priorities that favor sustainable energy (the Norwegian Sovereign Wealth Fund, Saudi Arabia's Public Investment Fund, European Investment Bank, among others), the developing nations update their climate policies to become eligible for the ODA.

Examining NHRE development in energy-rich Kazakhstan, Turkmenistan and Uzbekistan, the NHRE deployment dilemma for the fossil-fuel-rich (FFR) developing economies is multidimensional. That is, Boute and Zhikharev [61] argue that incumbent energy companies acquire powers of vested interests in solar PV manufacturing sector and accelerate RE diffusion in Russia. This study draws relevant lessons for hydrocarbons-rich Kazakhstan. Aligning with Moe [62], arguments drawn for other cases, Boute and Zhikharev [61] (p. 1), believe that "(t)he manufacturing of clean energy equipment rather than the decarbonization of the energy system, drives Russia's renewable energy policy". This assessment is supported by the findings that the development of NHRE is associated with larger innovation intensity in the energy sector and economy at large [11,13,63]. Explaining the rationale behind, Mäkitie et al. [2] think that the turbulences at the commodities markets drive the reorientation of the incumbent national fossil fuel industries towards locking out the lower carbon alternatives.

The diffusion of renewable energy proliferates in economies with adequate technological, socio-economic, and political institutions. The most critical for energy transitions institutional traits involve a decent degree of flexibility and adaptability [64–66]. The problem in energy rent dependent countries is that their governments are reluctant to initiate transformations because of the associated risks of destabilization of the incumbent authority and propagation of political and socio-economic turbulences [48,67]. In authoritarian rent dependent economies, the political elites construct fiscal systems upon a heavy reliance on the taxation of resources. This creates an image of a state being paternalistic vis-à-vis its citizens (ample examples of this kind are the rationed per capita or per household quantities of free of charge electricity, gas, and gasoline). In reality, however, such a system fosters rampant clientelist traditions and hinders governments' accountability [10,68]. It is for the virtues of interdisciplinary frameworks instrumental for the analysis of complex phenomena of NHRE diffusion that the concepts of institutional theory [69,70], political economy [71] and varieties of capitalism [26,72,73] are increasingly appreciated. The RE development can be enhanced by the efficient institutions and, in turn, the sector can become a driver for a range of positive shifts in the national energy sector and the economy at large. On the contrary, the RE sector may be affected by the poor practices becoming yet another channel for syphoning off the national wealth [74,75]. Putting this in perspective, developing nations who lack their own financial capacities, tend to rely on FDI and ODA when deploying RE innovations. The effectiveness of external financing is influenced by the quality of national institutions [76].

To recapitulate, developing economies with higher income level, more diversified energy mix, better educational attainment, greater economic openness, higher quality institutions, more substantial dependency on imported energy, as well as with the endorsed essential domestic RE policies and the manifested commitment to the Kyoto Protocol, are more likely to engage in NHRE deployment. Concurrently, economies with a considerable dependency on hydropower, expanding economy and rapidly rising energy demanding a profound reliance on ODA and FDI are less motivated to develop NHRE. However, and this is important for our further analysis, the review has elucidated that the effects of some determinants are ambiguous or changing over time. For instance, as a result of donors' changed sustainability priorities, the impacts of ODA and FDI seem to be switching to positive ones; or, the factor of vested interest in some post-Soviet and developing hydrocarbon-rich countries is conducive to NHRE diffusion.

Putting these observations in perspective, a variety of determinants turns Kazakhstan into the fittest candidate for the NHRE development. A number of factors seem to be favoring NHRE

deployment in Uzbekistan and Turkmenistan. While Kyrgyzstan and Tajikistan seem to be less equipped to engage in RE diversification, their prospects for doing so are improving. In the following section, we outline the framework, upon which we check our hypothesis that more developed economically and institutionally countries in the region are more successful in NHRE deployment.

2.2. Methodological Framework and Data

To assess the Central Asian economies' NHRE deployment status, we apply the two-stage analytical framework, which incorporates insights from the reviewed existing research and builds upon the adopted practices [77]. First, we evaluate the ability of national energy systems to meet the needs of respective Central Asian economies across three interacting dimensions: economy, security, and sustainability (Table 1). At the second stage, we assess the countries' preparedness to embrace NHRE. In doing so we examine the structure of the incumbent energy systems, and analyze the adequacy of the existing RE policies, intuitions, investments, infrastructure and human capital.

Table 1. Analytical Framework Energy System's Performance—Deployment Readiness (Source: author, adapted from [77] (p. 31); [78]; [79] (pp. 185–187)).

Characteristics	Dimensions	Key Indicators
Energy system performance	Economy	Economic growth, %
		Population growth, %
		Electrification rate, % of population
		Energy rent, % to GDP
		Energy subsidies, % to GDP
		Net fuel exports, % of TPES
	Energy Security	Net energy imports, % of TPES
		Diversity of energy exports/imports
		Quality of electricity supply
	Environmental Sustainability	Energy intensity
		CO_2 intensity
NHRE deployment readiness	Energy System Structure	Energy supply per capita
		Electricity system flexibility, shares of hydro, gas and oil
		Share of electricity from coal
		Share of electricity from NHRE
		Share of global fossil fuels reserves, %
	Regulation and Political Commitment	State goals
		Factors affecting state goals (dependencies on external factors)
		NDC commitment
		RE policy stability
		Energy efficiency regulations
		RE regulations
		Energy access regulations
	Institutions and Governance	State capacity and stability
		Special interests
		Corruption
		Rule of law
		Credit rating
	Capital and Investment	Investment freedom
		Access to credit
		New NHRE capacity built, % of change

	Infrastructure and Business Environment	Infrastructure for extraction, transportation, conversion and use Technology availability Logistics performance Innovative business environment Internet users, % of population Mobile telephone, units per 100 people
	Human Capital	Education quality

For the quantitative assessments, we employ a vast range of data sources (Appendix A). The country-level analysis additionally incorporates relevant data published by the national ministries of energy (or respective agencies in charge of RE regulation) and national statistical services. State-owned energy companies' information helps comprehend the hierarchy of the national energy sectors and the structure of domestic electricity markets. Out of the five countries covered by this study, Turkmenistan has the sparsest data.

Similarly, the qualitative analysis draws upon a variety of accounts. A critical review of program documents (concepts and strategies), explaining the nations' long-term visions of the RE roles and outlining principal directions of the governmental policies, helps identify numerical parameters of energy transitions and enables cross-country comparisons. Examination of the regulatory aspects of RE development, such as tariff policy, pricing, taxation, foreign trade, and investment-related provisions, substantiates the analysis.

3. Analysis of Energy System Performance

3.1. Energy System and Economy

Kazakhstan and Turkmenistan are the wealthiest economies in Central Asia (Table 2). The least developed in the region, Kyrgyzstan and Tajikistan have lost precious resources and time to the revolutions of 2005 and 2010, and to the civil war of 1992–1997 and the insurgency of 2010–2015, respectively. These two could not catch up with the market transitions. Unlike the peers in the region, Uzbekistan had not experienced deep economic declines throughout its independency. However, due to its large and continuing-to-grow population, the country still has comparatively low per capita income.

Table 2. Central Asian Economies' Profiles (Source: author, based on World Bank data).

Indicators	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Population, 2019, mn	18.3	6.32	9.1	5.9	32.5
Population growth, 1992–2018, an. avg., %	0.39	1.29	1.93	1.61	1.68
GDP growth, 1992–2018, an. avg., %	3.47	1.93	2.28	5.04	4.49
GDP per capita growth, 1992–2018, an. avg., %	3.04	0.60	0.31	3.39	2.76
GDP per capita, PPP (constant 2011 international $), 2018	24,738	3447	3061	17,129	6240

Note: the latest available data for Turkmenistan are as of 2014.

Central Asian countries continue subsidizing energy. Measured as a percentage to GDP, the subsidies were the highest in Kyrgyzstan (26.4%), followed by Uzbekistan (26.3), Turkmenistan (23), Kazakhstan (11) and Tajikistan (7.1%) [80]. This makes conventional energy sources difficult to compete with. In 2017, the costs of NHRE in Kazakhstan were four- to five-fold higher than that of traditional. That is, the average cost of one kWh generated at a coal-fired facility was 7–8 tenge (US$ 0.02), while a kWh generated at a wind farm cost 22 tenge (US$ 0.07), and even more at a solar photovoltaic—34 tenge (US$ 0.1) [81]. In Kazakhstan, the return on investment in solar PV energy is

20 to 25 years, which is unacceptable to investors [82]. Low energy tariffs undermine the competitiveness of NHRE and discourage investment in new technologies.

The effects of energy exports on the domestic economies are presented in Table 3. Since the early 2000s, oil output and exports (primarily to Europe) have been growing rapidly in Kazakhstan. Turkmenistan's gas production and exports started to increase after the commencement of gas pipeline to China in 2009. In both countries, the energy-GDP growth has been weaker and less stable than that of non-oil GDP. The contribution of oil revenues to Kazakhstan's budget has become less significant (comparison of the fiscal and external breakeven price supports such idea); correspondingly, the non-oil revenues have been increasing. In Turkmenistan, gas revenues continue to play a considerable role.

Table 3. Selected Parameters of Fossil-Fuel-Dependent Economies (Source: retrieved from http://data.imf.org/?sk=4CC54C86-F659-4B16-ABF5-FAB77D52D2E6&sId=1390030109571).

Indicators	Country	Average			Projections		
		2000–15	2016	2017	2018	2019	2020
Oil GDP Growth, %	Kazakhstan	6.6	−2.9	8.7	8.4	−1.4	1.1
	Turkmenistan	9.0	−4.8	1.7	5.4	6.6	4.1
Non-Oil GDP Growth, %	Kazakhstan	7.6	2.4	2.7	2.7	5.6	4.8
	Turkmenistan	10.7	8.5	7.3	6.3	6.3	6.4
Crude Oil Exports, mb/d	Kazakhstan	1.16	1.28	1.41	1.52	1.48	1.49
Natural Gas Exports, 1000 cm/d	Turkmenistan	0.60	0.65	0.66	0.64	0.72	0.76
Fiscal Breakeven Oil Price *	Kazakhstan	76.64	113.51	105.21	37.89	57.83	57.84
	Turkmenistan	69.10	45.95	55.94	63.93	58.91	57.62
External Breakeven Oil Price **	Kazakhstan	85.93	86.71	82.67	81.53	81.50	77.07
	Turkmenistan	80.82	58.07	53.96	28.68	48.46	47.25

Notes: * the oil price at which the fiscal balance is zero; ** the oil price at which the current account balance is zero; mb/d—million barrels a day; cm/d—cubic meters a day.

3.2. Energy Security

The Soviet era-built formats of regional energy cooperation in Central Asia have been largely terminated [83]. A result of disrupted regional frameworks, poor in fossil fuels and rich in hydropower resources Kyrgyzstan and Tajikistan, became vulnerable to energy deficits, especially in winter. Tajikistan and Kyrgyzstan, who generate, respectively, 98% and 85% of electricity at large-scale hydropower plants (LSHPP), are net-importers of energy (30% and 50% of their energy use, respectively). The other nations in the region face the challenges of water availability, as the dependence on transboundary water ranges from critical for Turkmenistan (94%) and Uzbekistan (77%), to high for Kazakhstan (42%) [84].

Kyrgyzstan and Tajikistan are increasingly challenged to match their growing demand for electricity with the existing generating capacities. Kyrgyzstan's hydropower resources are being exploited at 13% of potential [41], yet power deficit, according to local sources, reaches 25% in winter. One of the peculiar features of Kyrgyzstani HPPs is a high ratio of their wearout, for the major generating capacities were built in the 1960s and 1970s, including the largest Toktogul HPP; the majority of small-scale HPPs were constructed in the 1940–1960s. Tajikistan is ranked the top in Central Asia and the 8th in the world for its hydropower resources, with only about 5% of hydro stock being harnessed [41]. Yet, in 2009, Tajikistan had a severe energy crisis (exacerbated by the discontinuation of the Central Asian Power System format). About 60% of Tajikistan's HPPs require urgent renovation.

Ageing power generation, transmission and distribution infrastructure affects the quality of electricity supply in Central Asian economies. Electricity transmission losses, blackouts and low-quality services are affecting the nations' economic prospects. The World Bank assesses electricity losses to output in Kyrgyzstan at 24%, Tajikistan—17, Turkmenistan—12, Uzbekistan—9 and Kazakhstan at 7%. The number of power outages in a typical month for Tajikistan is 6.1 occasions of blackouts and for Uzbekistan 5.7 outages. Access to electricity in the rural areas, according to the World Bank's SE4ALL, in Kyrgyzstan is 99.7%, in Tajikistan is 99.3%, and in the rest of Central Asian economies is 100%. Yet, according to the national statistics, 10% of the rural population have no access to electricity [85]. Furthermore, an estimated 2 million households in Kyrgyzstan and Tajikistan [80], but also in Uzbekistan [86], experience energy poverty.

3.3. Environmental Sustainability

Expectedly, FFR economies have a high reliance on fossil fuels and higher per capita energy use (Table 4). The efficiency and productivity of energy use are the lowest in Uzbekistan and Turkmenistan. Tajikistan, Kazakhstan and Kyrgyzstan demonstrate higher energy use efficiency and productivity. In Tajikistan and Kyrgyzstan, this is likely to be influenced by the modest shares of industry in GDP (around 25% and 30%, respectively) and energy deficits. In Kazakhstan, the metrics have improved over time, due to technological upgrades. Turkmenistan and Uzbekistan increased the environmental load, which is measured through the CO_2 damage and ratio of greenhouse gas emissions versus 1990.

Table 4. Environmental Sustainability (Source: author, based on World Bank data).

Indicators	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Fossil fuel energy consumption, 2014, % of total	99.17	75.48	45.98	n/a	97.74
Energy use, kg of oil equiv. per capita, 2014	4434.64	650.40	339.85	4893.41	1419.48
Energy use (kg of oil equivalent) per $1000 GDP (constant 2011 PPP), 2014	188.01	204.73	131.71	341.43	230.21
Energy intensity level of primary energy, MJ/$2011 PPP GDP, 2015	7.92	8.64	5.01	13.86	9.99
GDP per unit of energy use, constant 2011 PPP $ per kg of oil equiv., 2014	5.32	4.88	7.59	2.93	4.34
GDP per unit of energy use, PPP $ per kg of oil equiv., 2014	5.62	5.16	8.02	3.09	4.05
Adjusted savings: energy depletion, 2017, % of GNI	6.21	0.02	0.04	5.78	4.62
Adjusted savings: CO_2 damage, 2017, % of GNI	5.74	5.27	2.40	6.20	6.23
Total greenhouse gas emissions, 2012, % vs. 1990	−1.55	−58.55	−29.09	13.33	4.64

Note: the latest available (as of 25 March 2020) data are used.

Table 5 shows the significant environmental impact of energy sectors in FFR economies. Despite comparatively low levels, energy-related environmental burden in Kyrgyzstan and Tajikistan is likely to exacerbate, given the technical condition of the nations' generating capacities.

Table 5. Energy Sectors' Environmental Footprint (Source: author, based on World Bank data).

Indicators	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Energy related methane emissions, 2008, % of total	57.04	7.45	13.36	75.53	59.70
CO_2 emissions from electricity and heat production, 2014, % of total fuel combustion	63.27	25.84	4.29	35.82	42.45

Note: the latest available data are used.

4. Analysis of NHRE Deployment Readiness

4.1. Energy System Structure

Based on the WB data, electricity consumption across Central Asia varies significantly, with the gap between the highest consumption in Kazakhstan and the lowest in Tajikistan exceeding three times. Kazakhstan and Turkmenistan surpass the world average, and Kazakhstan outstrips the average in its income group. All Central Asian economies have higher electricity consumption than the economies in their respective income groups, which can be explained by the Soviet-era legacy of total electrification.

Central Asian energy systems demonstrate low flexibility, as they exhibit a high reliance on one principal source (Table 6) [87].

Table 6. Total Primary Energy Supply (TPES) by source, 2016, % (Source: author, based on IEA World Energy Balances 2018).

Indicators	Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Coal	43.25	23.53	20.15	0	4.11
Oil	20.21	44.54	32.05	23.35	6.34
Gas	35.14	6.21	0.10	76.61	86.85
Hydro	1.22	25.70	47.70	0	2.70
Biofuels and waste	0.13	0.03	0	0.04	0.01
Geothermal, solar, etc.	0.04	0	0	0	0

Kazakhstan primarily uses its most abundant energy resource—coal (Tables 6 and 7), which is not sustainable environmentally. The second principal energy source—gas, is not so plentiful, besides it is important for maintaining Kazakhstan's oil production as well as expansion of export [44,88]. Kyrgyzstan relies heavily on imported oil, which is not a sustainable option for a low-income economy. Tajikistan relies mostly on hydropower, which is in line with its endowment profile. Similarly, Turkmenistan has a preference of natural gas. Uzbekistan's reliance on natural gas appears to not be sustainable in the long-run and contradicts the country's ambitions to augment gas exports. A larger role of domestically plentiful coal is not an environmentally responsible choice, especially given the fact that Uzbekistan already exceeded its 1990 emissions levels.

Table 7. Asian Countries' Energy Resource Endowment (Source: author).

Indicators	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Coal, billion tonnes, bt	31.3	0.9	3.6	-	3.3
Reserves to production, R/P, years	506				458
Reserves to consumption, R/C, years	628				444
Natural gas, trillion cubic meters, tcm	2.4	0.006	0.006	7.5	1.8
Reserves to production, R/P, years	41			317	21
Reserves to consumption, R/C, years	50			687	28
Oil, billion barrels, bb	30	0.04	0.01	0.6	0.594
Reserves to production, R/P, years	43			9	34
Reserves to consumption, R/C, years	238			14	38
Hydro, megawatt, MW	20,000	26,000	40,000	-	1700

Note: R/P and R/C are computed based on BP 2019.

In such a context, it is reasonable to consider closely the alternative energy sources, because all nations have plentiful RE potential. Operating by available assessments (Table 8), Kazakhstan could target at larger deployment of solar photovoltaic and wind energy, Kyrgyzstan and Tajikistan—solar, Turkmenistan—solar and wind energy, and Uzbekistan could aim at exploiting the energy of the sun and biomass.

Table 8. Technical Potential for Installed Renewable Electricity Capacity in MW (Source: author, compiled based on UNDP Renewable Energy Snapshot for respective Central Asian countries).

Source	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Wind	354,000	1500	2000	10,000	1600
Solar PV	3,760,000	267,000	195,000	655,000	593,000
Biomass	300	200	300	not significant	800

Currently, Kazakhstan is most actively engaged in NHRE deployment (Table 9). In 2018, the country had 60 RE projects operating, and more than 50 projected with the total capacity to reach 2353 MW in 2020 [89].

Table 9. Deployment of RE in Kazakhstan (Source: author, based on annual reports of Kazakhstan's Ministry of Energy, http://energo.gov.kz/index.php?id=20855).

Parameter	2014	2015	2016	2017	2018
Installed capacity, MW, including:	177.52	251.5	295.7	342.3	531
wind	52.81	71.76	98.16	112.4	121.5
small-scale HPP	119.27	122.3	139.9	170.8	200.3
solar	5.04	57.07	57.3	58.8	209
biofuels	0	0.35	0.35	0.35	0.35
Output, mn kWh, including:	578.17	703	927.9	1102	1352
wind	17.4	131.8	262	339	401.9
small-scale HPP	558. 15	424.1	577.2	649.1	807.4
solar	2.62	46.96	86.8	114.3	142.3
biofuels	-	0.48	1.86	0.06	1.3
RE electricity in total output, %	0.62	3.16	0.98	1.08	1.27
RE electricity output growth, y-o-y, % (*)	8.90	21.59	24.10	15.80	19.00

Note: (*) according to Ministry of Energy.

Kazakhstan, especially its southern regions, has high insolation: between 2200 and 3000 h of sunlight per year, or equivalent to 1200–1700 kW/m^2·annually [90]. This makes both concentrated solar thermal and solar photovoltaic solar power generation suitable technically and feasible economically. In 2019, in cooperation with the EBRD's and European companies, Kazakhstan accomplished 100 MW a solar power station, which is the largest in Central Asia. Additionally, Kazakhstan possesses an exceptionally large potential for wind generation [27,28]. Geographically, the Dzungarian Gates, Mangystau Region, the Karatau Peak and the Chu-Ili Mountains are the most suitable locations for wind power [91]. Currently, Kazakhstan utilizes only a small portion of this potential having 14 wind farms (Yerementau in Akmola oblast' and Kordai in Zhambyl oblast', among others) of the total installed capacity of 180 MW (as of 2019). Despite the significant role of agriculture in the Kazakhstani economy, only 10% of the agricultural residual is used [92]. The only large-scale facility Vostok Biogas operates in the Kostanai region.

4.2. Regulation and Political Commitment

Readily available scores on RE policy characterize Central Asian countries progress in setting up regulatory environment for RE development (Table 10). The only country in the region with all the elements of RE policy introduced, Kazakhstan has the highest ranking. Turkmenistan has not addressed the key policy areas (such as legal framework), with other aspects suffering noticeable flaws. The rest of the group are in same ranking range. Uzbekistan has been actively developing RE regulation, which resulted in a noteworthy ranking improvement.

Table 10. Renewables (RE) Policy Scores, 2017 (Source: author, based on Renewable Indicators for Sustainable Energy, World Bank, http://rise.worldbank.org/).

Indicators	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Legal framework for RE	100	100	100	0	100

Planning for RE expansion	40	5	35	3	49
Incentives and regulatory support for RE	35	19	38	0	38
Attributes of financial and regulatory incentives	33	33	17	8	0
Network connection and use	48	30	32	27	26
Counterparty risk	64	38	30	17	6
Carbon Pricing and Monitoring	100	0	0	0	50
Overall score 2017 (2010)	60 (44)	32 (22)	36 (29)	8 (3)	38 (9)

Note: 100—maximum score.

A more detailed overview of regulatory provisions for NHRE deployment in Central Asian countries is presented in Shadrina [83]. Arranged in a comparative format, Appendix B helps clarify the principal components of the countries' approaches.

Kazakhstan endorsed long-term development strategies Kazakhstan-2050 and Concept for the Transition towards a Green Economy (which formulates the goals for 2020, 2030 and 2050). These documents state the quantitative objectives with a focus on growth and economic diversification away from the reliance on the extractive industries. Such ideas, however, are not adequately translated into actions. A significant gap exists between official goals and efforts made to achieve them. That is, the concept's goal to increase the share of wind and solar in electricity generation to 3% by 2020 has not been met. Similarly, the concept's goal of decreasing CO_2 emissions in the energy sector to 2012 levels by 2020 has also not been fulfilled. Already, in 2016, CO_2 emissions were 10% higher than the 2012 level, and no downward trend has set in since then.

Kyrgyzstan adopted numerous documents, "but the lack of a clearly defined hierarchy of documents, budget for the objectives and responsibility for implementation make it difficult to identify the government's key development objectives" [16]. For instance, the National Development Strategy to 2040 mentions that renewable energy will occupy 50% in the country's energy mix by 2040. However, Kyrgyzstan has no such projects (except for a few in the hydropower segment) planned. Despite the adoption of long-term programs, the efficacy of the National Development Strategy to 2040 and Strategy for Sustainable Development to 2040 is highly questionable. Neither of the two sets out measurable goals, identifies the responsible governmental agencies, provides a clear division of functions among the stakeholders and allocates the implementation budgets. Moreover, the Green Economy Concept has no associated timeline and its objectives do not specify delivery dates. Kyrgyzstan's existing strategies do not address environmental agenda. In 2019, the country was the last in Central Asia to ratify the Paris Agreement, but it did not yet adopt a long-term low-emission development strategy. Long-term objectives and numerical targets for emissions reduction and climate-change resilience are not integrated into Kyrgyzstan's strategies.

Tajikistan adopted a large number of program documents. However, there are incontinences between the goals and priorities set in various program documents. For example, the National Development Strategy to 2030 (2016) criticizes the weak diversification of energy resources and the absence of NHRE in the country's energy mix. The Program for Development in Mid-Term Perspective 2016–2020 (2016) also points out the underdeveloped energy infrastructure, lack of access to electric power in remote areas and jeopardized energy security, and emphasizes the importance of energy sources diversification with a larger role to play by solar, wind, biomass and biogas. However, the Power Sector Development Master Plan (2017) is devoted entirely to the hydropower sector, stating in passing that wind, solar, geothermal and biomass energy do not deserve consideration as the priority areas. Another example is that, despite several overlapping goals, the National Development Strategy to 2030 does not refer to the Sustainable Development Transition Concept to 2022. Strictly speaking, the latter does not present an adequate vision for the nation's sustainable development. The most obvious reason is that the document was endorsed in 2007, when the overall awareness of sustainability was sufficiently lower. Yet, this also shows that the regulatory environment Tajikistan's suffers from the discrepancy between all kinds of documents (master plan, program, strategy) in both time-horizon and target-setting dimensions of hierarchy. Strained

financially, Tajikistan has not been sufficiently selective in its approach to foreign investments. OECD (2019) notes that Tajikistan mostly endorses projects without screening them against the national developmental and environmental goals, and without intermediate and final evaluations of approved investment projects. Another clearly identifiable aspect of officially endorsed program documents in Russian language is their poor linguistic quality.

Turkmenistan has adopted several strategic documents, such as the National Socioeconomic Development Program for 2011–2030 (2010), which has since been supplemented with a shorter-term document for 2019–2025. While these documents present Turkmenistan's vision to diversify away from its reliance on natural gas, they do not offer a concrete set of intermediate steps. Turkmenistan's strategic documents can be assessed as the least actionable; they "do not specify which state body takes ultimate responsibility for the delivery of goals, and there are no quantitative—or at least verifiable—goals against which to measure progress on implementation" [16] (p. 222).

Uzbekistan has adopted the Action Strategy on Five Priority Directions for the Development 2017–2021. In addition, every year the government publishes a government program contributing to the five policy directions: governance, rule of law, economic liberalization and development, social reforms, and security. However, some of the policy goals are not the useful benchmarks. For example, the index selected for infrastructure is linked to the Global Competitiveness Index, which has never ranked Uzbekistan, and therefore cannot serve as a mark against which to compare. Additionally, while the Action Strategy outlines a vision for the nation's development throughout 2021, Uzbekistan has not yet formally adopted a longer-term development strategy. Similarly, the strategy for RE development, drafted in 2019, has not been adopted yet. On the other hand, Uzbekistan applies innovative approaches to institution- and capacity-building. One of interesting experiences is Buyuk Kelajak, a non-governmental organization created in 2018. Connecting 240 expatriates from over 30 countries, this Expert Council developed Development Strategy Framework of the Republic of Uzbekistan until 2035. Although the government does not formally recognise the Strategy 2035 objectives, the Buyuk Kelajak initiative includes the agenda for RE and sustainable development.

Even though Central Asian countries submitted their Intended Nationally Determined Contribution (INDC) towards the achievement of the global goal of the UN Framework Convention on Climate Change (UNFCCC) in 2015 (Uzbekistan did so in 2017), they do not seem to be particularly concerned about environmental sustainability. Because of protracted economic decline in the 1990s, the Central Asian countries still have emissions growth "reserve" against 1990 (Kazakhstan and Tajikistan), and even against 2010 (Kyrgyzstan, Turkmenistan and Uzbekistan). Yet, by joining the UNFCCC and setting the INDC, more developed economies in the region Kazakhstan, Turkmenistan and Uzbekistan articulate that they share and support globally pursued ideas of sustainability. It appears that Kyrgyzstan's and Tajikistan's motivations are more pragmatically driven, because, as was pointed out in the literature review, the external financing, including aid, is increasingly linked to the sustainability agenda.

4.3. Institutions and Governance

Analysis in this section incorporates such rankings as the ease of doing business ranking (EDBR), corruption perception ranking (CPR) and global competitiveness ranking (CR) (Table 11). Out of 190 countries covered by the EDBR, Kazakhstan is leading in the group and progressively improving its position. Kazakhstan's strongest achievements are "enforcing contracts" (4th) and "protecting minority investors" (7th). The weakest positions are "trading across borders" (105th) and "getting electricity" (67th). Here, too, Uzbekistan most significantly improved its ranking, with the best position being "starting business" (8th) and the worst "trading across borders" (152nd). Kyrgyzstan keeps falling in the ranking since 2016, when it held the 67th position versus the 80th most recently. Its best performance is in "registering property rights" (7th) and the poorest in "getting electricity" (143rd). Tajikistan gradually moves up, yet in the lower part of the ranking (106th). Ease of "getting credit" is Tajikistan's strongest point (11th), while "getting electricity" is the weakest (163rd).

Table 11. Selected Rankings for the Quality of Institutional Environment in Central Asian Economies (Source: author, based on Ease of Doing Business, http://www.doingbusiness.org; Corruption Perception Ranking, https://www.transparency.org; Global Competitiveness Ranking http://reports.weforum.org).

	Ease of doing Business Rate (EDBR)				Corruption Perception Rate (CPR)					Global Competitiveness Ranking (CR)		
Years	**Kazakhstan**	**Kyrgyzstan**	**Tajikistan**	**Uzbekistan**	**Kazakhstan**	**Kyrgyzstan**	**Tajikistan**	**Turkmenistan**	**Uzbekistan**	**Kazakhstan**	**Kyrgyzstan**	**Tajikistan**
Latest *	25	80	106	69	124	132	152	161	158	55	96	104
2015	77	102	130	82	123	123	154	154	153	50	108	91
2010	63	41	152	164	105	164	151	172	172	67	123	122

Note: * the latest available, EDBR 2020; CPR 2018; CR 2019.

Corruption seems to be a growing problem in all countries in the region. Even the early leader, Kyrgyzstan has somewhat retreated from its anti-corruption course.

Kazakhstan's principal components of competitiveness are "labour market", "business dynamism" and "ICT adoption", while most negative effects are generated by mediocre performance of "financial system" and nation's "health". Kyrgyzstan's overall modest competitiveness is especially affected by its weaknesses in "innovation capability", "market size", "product market" and "financial system". Tajikistan has low metrics on all the pillars of competitiveness, but especially problematic are "market size", "ICT adoption", "innovation capability", "financial system" and "business dynamism". While Turkmenistan and Uzbekistan are not included in the CR, some relevant perspectives can be drawn from their Indices of Economic Freedom (Appendix C). The two economies experience a lack of financial and investment freedoms and problems with government integrity. Turkmenistan's economy is additionally affected by lack of labor and business freedoms, judicial efficiency and property rights protection.

Indicating the ease of access to capital, credit rating is another important characteristic of the institutional quality. Table 12 indicates that Kazakhstan is the only country in the region with investment-grade credit ratings from the top agencies. Uzbekistan has made definite progress, although it is assigned the non-investment speculative grade by S&P and Fitch, and highly speculative by Moody's. In the regional context, Uzbekistan is ahead of Kyrgyzstan and Tajikistan. The improvement of credit rating up to investment grade is essential for lowering the borrowing costs for respective governments and better business environment in these countries.

Table 12. Central Asian Economies' Sovereign Debt Credit Ratings (Source: author based on Standard and Poor, Moody's and Fitch).

Country	S&P	Moody's	Fitch
Kazakhstan	BBB-/lower medium grade	Baa3/lower medium grade	BBB/lower medium grade
Kyrgyzstan		B2/highly speculative	
Tajikistan	B-/highly speculative	B3/highly speculative	
Uzbekistan	BB-/non-investment grade speculative	B1/highly speculative	BB-/non-investment grade speculative

Note: no data on Turkmenistan.

Polity IV (Project, Political Regime Characteristics and Transitions), which characterizes democratic and autocratic "patterns of authority" and regime changes, evaluates all Central Asian economies, except Kyrgyzstan, as authoritarian, with the strongest authoritarian hold marked for Uzbekistan (−9), followed by Turkmenistan (−8), Kazakhstan (−6) and Tajikistan (−3). Kyrgyzstan is evaluated as a democratic nation (+8). While Polity IV is acclaimed for being one of the most unbiased indexes and therefore is extensively employed in modern econometric research, it is not immediately clear why Uzbekistan is perceived to be more authoritarian than Turkmenistan, or why Tajikistan is perceived to be so much less authoritarian than Kazakhstan and Uzbekistan. Additionally,

Kyrgyzstan's outstanding position appears to be not so well-grounded, as the country faces similar challenges in the realm of good governance.

4.4. Capital and Investment

Capital and technical expertise are invaluable for NHRE diffusion. Limited access to affordable bank loans and absence of local green financing schemes, high initial investment costs and risk deter potential investors in the region. Domestic lending interest rates, for example, in Kyrgyzstan and Tajikistan, are close to 20% and 30%, respectively. Lacking domestic financial resources and efficient institutions, the Central Asian countries remain dependent on external funding. Yet, even the costs of external financing are indicated as one of the factors behind low price competitiveness of RE. In Kazakhstan, 70% of RE projects are implemented with the international institutions' financing at 12–13% and 10–15 years payback period (whereas the world's average interest rate for RE projects varies within 1.5% to 3%). The average tariff for electricity generated at externally financed RE projects is assessed at 7 cents/kWh, while electricity from traditional sources is priced at 2 cents/kWh [93].

Compared to other economies in the region, the investment climate in Kazakhstan is more attractive, which makes the country the main recipient of foreign direct investments (FDI) [16]. According to the National Bank of Kazakhstan, in 2018, the Netherlands was the largest investor (30.29%), followed by the US (22.02%), Switzerland (10.47%), Russia (6.18%) and China (6.08%). Traditionally, the oil and gas sectors are the largest recipient of FDI (49.80% in 2018). In Kazakhstan, NHRE projects are financed by ABB, KB Enterprises, Solarnet Investment GmbH, United Green, Nomad Solar (a Kazakhstani company co-owned by Total Eren SA of France and Access Infra Central Asia Ltd. of the UAE), to name but a few. However, a substantial role in NHRE development in Kazakhstan (and even more so in less developed economies in the region) belongs to the international financial institutions, most of all to the EBRD (who also assisted in setting the legal framework for RE), but also Asian Development Bank (ADB), Eurasian Development Bank (EDB) and the United Nations Framework Convention on Climate Change (UNFCCC)). Affiliated with Kazakhstan's sovereign wealth fund, Samruk-Kazyna Invest and Kazakhstan's national energy company Samruk Energy are often co-financing NHRE projects.

Kyrgyzstan offers some attractive regulatory elements, such as 10% profit tax. However, the government lacks the capacity for effective implementation, and the economy is afflicted with the poor quality of ageing physical infrastructure [16]. Climate change agenda becomes increasingly critical for Kyrgyzstan, as melting glaciers challenge the future of hydropower-centred energy. Close to 80% of FDI is absorbed by gold extraction and mining industries. Kyrgyzstan is at high risk of debt stress, with the gross debt equal to 94.58% of GDP (as of 2019). China is the largest investor and creditor of Kyrgyzstan. According to the Ministry of Finance, in 2018, 49% of FDI came from China. China's Exim Bank holds 44.8% of Kyrgyzstan's external public debt. The loans under the Belt and Road Initiative (BRI) have been actively used for funding various projects in the national economy, including the energy sector. Other origins of FDI are Russia (16%), Kazakhstan (8%), Germany (5%) and the UK (5%).

Tajikistan's strategy to attract FDI in metal extraction and energy also produced a significant risk of debt stress. The country's debt equaled 87.61% of GDP in 2019 (compared to 30% in 2015). 80% of the debt is held by China's Export-Import Bank. Payment defaults have led to debt settlements, including licenses for mineral extraction and even the transfer of sovereignty over disputed territory to China [16]. Like in Kyrgyzstan, investments in the energy sector in Tajikistan, are focused on hydropower. The Roghun Hydropower Plant is the pillar of the National Development Strategy of Tajikistan to 2030. Together with Kyrgyzstan, Tajikistan is engaged in the World Bank-funded Central Asia-South Asia Electricity Transmission and Trade Project (CASA-1000), which promises substantial electricity export revenues. Similar to other Central Asian economies, Tajikistan is involved in the Line D of the Central Asia-China gas pipeline.

Turkmenistan seeks larger FDI inflows, which is critical to its energy sector. The country's largest foreign investor is China, followed by Russia [16]. Turkmenistan has relatively low gross external debt, however, the debt to GDP ratio has been rising (25.9% in 2018). Turkmenistan does not

face energy security concerns of the kinds some of the neighbors do, but its reliance on China for natural gas exports exposes the economy to a profound market risk.

Since 2017, Uzbekistan has been working towards improving the investment climate. At the institutional level, new agencies have been created under the Ministry of Investment and Foreign Trade, including the Foreign Investment Agency. The dominance of state-owned enterprises (SOEs) persists, although Uzbekistan (like Kazakhstan) promotes the public-private partnerships for RE development (a respective law was endorsed in 2019). Russia is the largest investor in Uzbekistan, contributing 55% of FDI, followed by China (15%). Almost 50% of FDI is directed to the coal, oil and natural gas industries. In 2016, one of the most energy- and carbon-intensive countries in the world, Uzbekistan initiated the development of RE, particularly solar. With the help of NHRE, Uzbekistan aims to diversify energy mix, reduce dependence on gas and improve high-quality energy access.

Low FDI in NHRE across the region are not compensated by ODA allocations (Appendices D and E). In Central Asia, Kyrgyzstan and Tajikistan are the main recipients of aid (6.3% and 3.7% as a ratio to GNI, respectively), although the energy sector at large, and NHRE, in particular, are not among the priority areas for ODA donors.

By comparison, China's investments in energy sectors across Central Asia were significant (Appendix F). Since 2014, all energy-linked projects are implemented under China's BRI. It is easy to notice that the largest financing was allocated to conventional energy (gas and oil), although RE projects in Kazakhstan and Uzbekistan have also been receiving Chinese capital since 2016. Overall, about 2.62% of Chinese FDI in Kazakhstan and 4.3% in Uzbekistan were directed to RE projects.

To sum up this section, we agree with Boute [94] (p. 16), who notes that in Central Asia's downstream energy infrastructure, "… certain foreign investments … represent an informal constraint on energy market reform in the region … (F)oreign investments in Central Asian energy sector are a prominent example of geopolitical investments or infrastructure diplomacy". Boute further elaborates that "… (i)t is …difficult to find a commercial rationale to explain … foreign energy investments in the region, particularly in Tajikistan and Kyrgyzstan, where energy market conditions cause the greatest concern", but this does not prevent the Russian and Chinese SOEs from investing, because they pursue "… geostrategic interests, as part of the home state's infrastructure diplomacy" (p. 259).

Our analysis demonstrates that Kyrgyzstan and Tajikistan are easier targets for countries pursuing various interests in Central Asia. These economies trapped in a vicious circle of unaccomplished market reforms and weak institutions have developed a dependency on externally provided resources.

4.5. Infrastructure and Business Environment

Central Asian electricity markets share common regulatory principles and institutional characteristics originating in the Soviet era. However, the contemporary regulatory environment diverges significantly across the Central Asian states. The business environment for NHRE development in all Central Asian economies cannot be characterized as satisfactory; albeit, positive shifts are undeniable. An important parameter, the ease of receiving electricity, varies greatly by country. Uzbekistan streamlined the procedures (Table 13) and outperformed Kazakhstan, moving closer to the best performers. In all economies except for Kazakhstan, the costs of getting access to electricity undermine the credibility of earlier discussed parameter of 100% access to electricity. It is unlikely that the entire population in low-, lower- and middle-income economies can afford electricity access, whose cost exceeds per capita income by 4 to 9 times.

Table 13. Getting Access to Electricity (Source: Doing Business 2018. Reforming to Create Jobs. World Bank Group, 2018, pp. 170, 172, 198, 203; and Doing Business 2020. Country Profile (for each respective country); World Bank Group, 2020).

Parameter	Kazakhstan		Kyrgyzstan		Tajikistan		Uzbekistan	
	2018	2020	2018	2020	2018	2020	2018	2020
Getting electricity, rank	70	67	164	143	171	163	27	36
Distance to frontier score for getting electricity, 0–100	76.77	81.6	44.19	58.6	35	51.1	85.5	86.9
Procedures, number	7	6	7	7	9	9	4	4
Time, days	77	71	125	111	133	98	88	88
Cost, % of income per capita	47.4	35.9	814.4	683.9	811.5	867.8	833.1	441.2
Reliability of supply index and transparency of tariffs index, 0–8	8	8	0	4	0	4	8	8

Comparatively, Kazakhstan has done more profound transformations consistent with the logic of RE development. "Kazakhstan has opted to organize its electricity market in a quasi-liberalized basis, whereas the other Central Asian countries largely continue to follow the command-and-control (monopoly) approach" [94] (p. 89). Kazakhstan has privatized most of its power sector except for high voltage transmission. Around 97% of power plants are privately owned. State-owned electricity companies are system operator KEGOC (a 100% state-owned transmission and dispatch company assigned an exclusive right as a renewable energy buyer), electric power and electric capacity market operator JSC Kazakhstan Wholesale Electric Power Market (KOREM) and Samruk-Energo. The latter two are managed by the National Wealth Fund Samruk-Kazyna. 39% of total generating capacity is operated by Samruk-Energo. There are 20 regional distributing and more than 100 transmission companies. More than 160 retail supply companies (some are state-owned) purchase electricity from generating companies or at the centralized auctions, and sell it to the retailers and final consumers [95]. Wholesale electricity prices are determined by the market, which is administered by the market operator KOREM. Consumers can choose a provider of electric power. By 2025, a member of the Eurasian Economic Union (EAEU) Kazakhstan (together with Kyrgyzstan) will be integrated into the Common Electric Power Market (CEPM) [44,45].

In Kyrgyzstan, a state-owned OAO Elektricheskie Stantsii (OJSC Electric Stations) produces 98% of electricity and OAO NES Kyrgyzstana (OJSC National Energy Network Kyrgyzstan) dominates the transmission segment. The laws on Energy and on Electrical Power require the restructuring of both companies. Electricity generating plants of under 30 MW capacity can be privately owned. Legally, the electricity market is unbundled, but the system operators retain distribution and supply services.

In Tajikistan, the state owns the electricity generating company Bargi Tajiks. The only private OJSC Pamir Energy operates in the Gorno-Badakhshan Autonomous Region. Both companies are monopolists, providing all spectrum of services. In 2018, the unbundling of Barki Tojik into JSC Electricity Transmission Networks and OJSC Power Distribution Networks was decided.

In Turkmenistan, the electricity market is controlled by a vertically integrated state-owned Turkmenenergo. The company owns and operates the grid, generates and distributes electricity. Turkmenistan has been known for the lowest electricity tariffs in the world, but the worsening public finance forced the government to launch unpopular tariff reforms.

In Uzbekistan, the electricity market reveals a structural similarity with the already discussed examples. The state-owned electricity company UzbekEnergo generates 97.5% of the country's electricity [96]. The remaining share is the capacity of a small HPP, in which 84% is held by state-owned Uzsuvenergo and the remainder is owned by small block-stations enterprises. In 2019, the Strategy for the Development and Further Improvement of Energy Sector endorsed the unbundling of Uzbekenergo into generation, transmission and distribution segments. The generation and distribution sectors will be privatised, while the transmission will remain under the control of Natsional'nye Elektricheskie Seti Uzbeksiatna.

Characterising business environment, in Kazakhstan and Uzbekistan, the governments are aiming beyond a mere application of imported RE technologies and equipment; they target the localization of RE innovations. To this end, the manufactures of equipment for RE sector are granted tax exemptions and other stimuli. Price competitiveness and equipment efficiency are yet to be attained, however the political will to support the RE niche is in place. Additionally, to support the intraregional and international cooperation for RE diffusion, expertise exchange and investments facilitation, the two nations started holding relevant events. After the Astana EXPO-2017 "Future Energy: Solutions for Tackling Humankind's Greatest Challenge", Kazakhstan launched annual Central Asian Renewable Energy Summits. In 2018, Uzbekistan held the International Environmental Forum "Strengthening Cooperation for Environment and Sustainable Development" and decided to make the Central Asia Climate Change conference an annual event. Besides, the two countries regularly organize the international forums for RE investment and financing.

Other parameters helping assess the business environment for innovation intensive RE segment are the ratio of Internet users and the "number of mobile phone units per 100 people". On the first indicator, Kazakhstan (78.9%) and Uzbekistan (52.3%) lead, followed by Kyrgyzstan (38%). As far as the second metrics is concerned, Turkmenistan has the highest ratio (162.9), followed by Kazakhstan (142) and Kyrgyzstan (122.6). Surprisingly, Uzbekistan has only 75.9 units per 100 people.

4.6. Human Capital

Assessing human capital, we pay attention to a composite indicator called Education Index (EI), which in turn is a part of other aggregate indicator—Human Development Index. In 2018, traditionally the top in the group, Kazakhstan's EI was 0.817, Kyrgyzstan's 0.734, Uzbekistan's 0.718, Tajikistan's 0.673, and Turkmenistan's 0.628. In 2018, share of population with educational attainment "bachelor+" was assessed at 34.1% in Kazakhstan, 16.3% in Uzbekistan and 11.9% in Tajikistan. Thus, in this area, two leaders are clearly identifiable.

5. Discussion

We hypothesized that more advanced, economically and institutionally, nations are more likely to engage in NHRE diffusion. On economic performance, we showed through a range of indicators the supremacy of Kazakhstan and somewhat solid standing of Turkmenistan. Albeit distant from these two by the income level, Uzbekistan is the most dynamically transforming economy in the region with massive potential. We spare more attention to explaining the second component of our argument—the institutional quality, and the role it plays in NHRE development.

Unfortunately, frequent incorporation of this category in modern socio-economic research has not made the meaning of institutional quality absolutely lucid. This study did not aim at such clarifications for a reason of space; therefore, we skip discussion about the meaning of the category per se. We support our argument about the quality of institutions in Central Asian countries with the Institutional Quality Index (IQI), which incorporates assessments of political and market institutions. When, based on the results of our analysis, we claim that the institutional quality in Kazakhstan is superior compared to that of the peers in the region, we weigh our assessment against the evidence from other sources. Thus, according to IQI 2019, institutional quality in Kazakhstan was assessed as the highest in the region (0.4652, with political institutions assessed 0.2287, and market 0.7018). Kyrgyzstan was ranked the second (0.3824, 0.2528 and 0.5120), Uzbekistan the third (0.2280, 0.0728 and 0.3832), Tajikistan the fourth (0.2262, 0.0836 and 0.3689), and Turkmenistan earnt the lowest rank in the region (0.0560, 0.0453 and 0.0667).

One observation in relation to the quality of institutions is important. In the introduction, we characterized the EAEU's financing and Russia's investments in RE projects in Kazakhstan as a positive example. Why, then, has Russia's involvement in the energy sector in Kyrgyzstan been assessed as counterproductive? We offer the following explanation. Russia and Kazakhstan are often compared for a similarity of the paths of their economic transformations and institutional reforms. Over time, their economic systems (co-)evolved to yet again attain (à la post-Soviet) institutional compatibility and cohesiveness [44]. The cooperation builds upon mutually acceptable standards. To boost the attractiveness of such transactions, even higher than national benchmarks sometimes need to be followed. The case is different for Kyrgyzstan and Tajikistan, who did not implement profound transition reforms, and who, as we demonstrated, are often falling under the sway of Russia and China. To link this to the paper's argument that more advanced economically and institutionally countries are more likely to commence NHRE development, the underlying logic is that economically weaker nations develop external dependencies (Section 4.4) and stagnate being trapped by their own, as well as imported, institutional inefficiencies (Section 4).

The analysis of NHRE diffusion across Central Asia allows us to distinguish between three approaches. The first can be referred to as proactive, to reflect the nations' vision on RE diversification, their delivery of policies and their attempts to combine domestic financial and technological means with the international capacities. Two examples of such approach are Kazakhstan and Uzbekistan. The second approach can be described as reactive. The countries in focus are Kyrgyzstan and Tajikistan, who seem to retain their priorities for hydropower, signaling, at the same time, their intentions to introduce NHRE. Yet, such intentions are stated in unmeasurable form and the required regulatory mechanisms are largely missing. A clear example of such signaling is set by Kyrgyzstan, whose Green Economy Concept suggests attracting more FDI for sustainable infrastructure to meet the nation's SDGs. To some extent, the pursuance of such passive approach is understandable: the lower-income steadily growing economies with rapidly increasing population face a range of serious constraints in the energy sector, which they cannot address with their own scarce financial and technological resources. However, the reactive approach does not offer the long-term systemic solutions to the augmenting problems of these poorer economies in the region. Finally, Turkmenistan does not fit with the described approaches and deserves its own category, which we coin indifferent. Turkmenistan is a hydrocarbons abundant, relatively wealthy and utterly reclusive economy. Such set of characteristics determines the country's present energy mix with zero NHRE and explains the absence of prominent agenda for NHRE development. Yet, the indifferent approach contains potential risks, such as limited energy affordability (if energy export revenues plunge

following the collapse in the commodity markets, the government will no longer be able to subsidize energy), or limited energy accessibility (the Soviet era-erected facilities will eventually crumble and the government will need to repair or construct new energy infrastructure in rural areas). Denying any decent degree of openness for the entire economy, Turkmenistan has been limiting its contacts in the energy sector to one segment—natural gas, and one partner—China; a precarious setting.

6. Conclusions and Policy Implications

The paper examined the case of NHRE deployment in Central Asia. It demonstrated that more advanced economically and institutionally countries in the region are more motivated to commence NHRE development. The principal findings can be summarized as follows:

- NHRE deployment in Central Asia is uneven;
- The fossil-fuel rich and more developed Central Asian economies display higher commitment to NHRE, with Turkmenistan being an outlier;
- All Central Asian economies depend on external resources—innovation and capital—for NHRE development, but only lower-income Kyrgyzstan and Tajikistan develop detrimental dependencies; and
- Institutional quality allowing economic openness and boosting learning competencies is critical for NHRE advancement. This, in our view, explains non-engagement of Turkmenistan, Kyrgyzstan and Tajikistan in NHRE deployment.

Linking the identified approaches with policy implications, it seems to be appropriate to consider three possible formats. The first can be called "engage and cooperate", meaning that domestic and foreign partners—private, corporate or institutional—can have commercially or elsehow beneficial cooperation with the countries practicing the proactive approach to RE development. Because the motivation for NHRE development is initially in place in these countries, the domestic and foreign partners need to effectively communicate their priorities. The followers of proactive approach already act as regional anchors in the realm of NHRE development. By holding regular international symposiums and conferences, they offer platforms for productive communication among official, business and institutional stakeholders across a multifaceted agenda.

Policy recommendations corresponding to the second identified approach (reactive) can be called "learn and follow". Kyrgyzstan and Tajikistan shall realize that the sustainability agenda shall be pursued, not for hitting concrete short-term narrow goals (like getting the necessary funding), but rather for finding feasible solutions to the multifaceted problems these nations face (energy-water nexus, climate change, energy poverty, to name but a few). Given higher investment risks in these economies, the institutional investors are more likely partners, which makes policy recommendation easier to implement. To shift the dialogue to a more constructive format, the institutional investors shall apply stricter sustainability criteria when considering energy investment in such economies. After all, the educational support for forging better practices has been made available to these economies. To compete for ODA and FDI, the recipients are expected to demonstrate the adequacy of their regulatory and institutional capacities.

Policy recommendations for the third (indifferent) approach are the hardest to formulate. As the international cooperation necessitates a certain degree of economic openness and institutional compatibility, gradual progress in the regional (Central Asia—China gas pipeline) and international (TAPI gas pipeline) energy cooperation may help enhance communication among official, business and institutional actors. Again, regularly held summits for renewable energy development in Central Asia may assist greatly in diffusing knowledge, sharing the best practices and building institutional capacity.

This study is a result of meticulous work on collecting data and information, organising and analysing it. Yet, the study has a number of limitations. Some of the limitations are objective. For instance, it is impossible to apply statistical methods to the analysis of a phenomenon in its nascent form, when there is no sufficient data. Furthermore, even the traditional quantitative analysis is often problematic for the absence of data (as we have noted, this is especially the case for Turkmenistan).

When this paper has been almost finalised, a dam collapse in Uzbekistan occurred to cause large damage to the agricultural regions in neighbouring Kazakhstan. In such a context, we reiterate our argument that Central Asian nations need a more vigorous engagement in NHRE diffusion. To support the nations' endeavours, interdisciplinary scholarly efforts on a wide range of topics—from purely technical (like studies of the advantages of specific RE technologies) and narrow (like RE and women's empowerment) to broader (like intra-regional cooperation in distributed energy systems)—are timely and, hopefully, will follow before long.

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Appendix A

Table A1. Data Sources (Source: author).

Indicator	Data Source
corruption	Transparency International Corruption Perceptions Index (CPI)
education quality	Education Index (Component of Human Development Index, HDI)
electrification, use of solid fuels, share of electricity from renewables/coal/gas/hydro	World Bank, World Development Indicators (WDI)
energy access and use	International Energy Agency (IEA)
energy efficiency regulations, renewable energy regulations, energy access regulations	World Bank, Regulatory Indicators for Sustainable Energy (RISE)
energy subsidies, externalities	International Monetary Fund (IMF)
fossil fuel reserves, production, consumption	BP Statistical Review of World Energy (BP)
fuel imports and exports	World Trade Organization (WTO)
import diversity	United Nations Conference on Trade and Development (UNCTAD)
industry electricity price, quality of electricity supply, rule of law, access to credit	World Bank, Doing Business Indicators (DBI)
Institutional Quality Index (IQI)	Libertad y Progreso
investment freedom	The Heritage Foundation
nationally determined contributions (NDC) commitment	United Nations Framework Convention on Climate Change
new renewable capacity built, low-carbon industry jobs	International Renewable Energy Agency (IRENA)
official development assistance (ODA)	OECD Statistics, Creditor Reporting System (CRS)
policy stability, transportation infrastructure, availability of technology, quality of education	World Economic Forum Global Competitiveness Index (GCI)
Polity IV	Center for Systemic Peace

Appendix B

Table A2. Regulation and Political Commitment to RE Development in Central Asian Countries (Source: author)

	Specialised Agency	Programme Document, RE Targets	RE Law	Energy Saving & Climate-Change Policy	Membership in International Organisations
Kazakhstan	Green Economy Council within the Ministry of Energy	• National Concept for Transition to a Green Economy up to 2050 (2013): —alternative energy (including nuclear) in electric power generation to 3% by 2020, 30% by 2030, and 50% by 2050 —by 2020, 106 electricity generating units, capacity 3000 MW • Concept for Development of the Fuel and Energy Sector 2014–2030 (2014): —solar & wind 3% by 2020 and 10% by 2030 —development of RE technologies and infrastructure	• Law on Supporting the Use of Renewable Energy Sources (2013): —FIT for 15 years (2013–2028) for biomass, solar, wind, geothermal and HPPs of up to 35 MW —investment stimuli: subsidies equivalent to up to 30% of the costs related to land acquisition, construction, and equipment purchases	• energy saving: to reduce energy intensity by 25% by 2020, 30% by 2030, and 50% by 2050 against the levels of 2008 • facilitation of modernization of existing power generation, power grids, and oil refining installations • endorsement of 15% (2030) & 40% (2050) reduction in greenhouse gas emissions vs. 2012 level • policies to support the development and inclusion of available RE sources in the energy mix	Paris Agreement under the United Nations Framework Convention on Climate Change COP 21 (ratified in 2016), IRENA, INOGATE
Kyrgyzstan	Coordination Council for the Development and Improvement of the Legislative Framework in the Field of Energy Conservation and Energy Efficiency	• National Energy Program of the Kyrgyz Republic for 2008–2010 and the Strategy for the Fuel-Energy Complex Development till 2025 (2007) • Concept for Energy Sector Development to 2030 (2016) • National Development Strategy to 2040 (2018): —RES in energy mix 50% —energy intensity & efficiency—level of OECD countries • Green Economy Concept: "Kyrgyzstan—Country of Green Economy": —attract more FDI for sustainable infrastructure to meet SDGs	• Law on RES (2008): —FIT for up to 8 years to ensure the reimbursement of investment costs —imported equipment and materials for RES facilities exempt from customs duties —transmission companies to purchase RES electricity • Law on the Amendment of Some Legislative Acts in the Sphere of Renewable Energy (2019)	• Strategy for Sustainable Development to 2040 (2018): —development of infrastructure, 16 projects, $8.3 bn	INOGATE, in accession to IRENA, in the process of ratification of the Paris Agreement under the United Nations Framework Convention on Climate Change COP 21

Tajikistan		• Long-term Program for Building Small Hydro Power Plants for 2009–2020: 189 small HPPs, 103.6 MW total capacity • Targeted Program for the Widespread Use of RES (2007) • Program for the Development of RES and the Construction of Small Hydro Power Plants for 2016–2020 (2015) • Power Sector Development Master Plan (2017): —no room for RES	• Law on the Use of RES (2010, amendments in 2015): —FIT guaranteed for up to 15 years for electricity produced at wind, solar, geothermal, biomass, and hydro power (up to 30 MW) plants	• Concept for Transition to Sustainable Development till 2022 (2007) • National Development Strategy to 2030 (2016) —development of small-scale HPPs (no concrete targets) —development of RE (no concrete targets) • Programme for Development in Mid-Term Perspective 2016–2020 (2016): —diversification of energy sources, larger role of solar, wind, biomass and biogas energy	Paris Agreement under the United Nations Framework Convention on Climate Change COP 21 (2017), IRENA, INOGATE
Turkmenistan		drafted: Concept on RE Development in the Republic of Turkmenistan for 2020-2030	drafted: the Law on Renewable Energy	• National Strategy on Climate Change (2012) • the Law on Environmental Assessments (2014) • National Programme for Energy Saving for 2018–2024 (2018)	Paris Agreement under the United Nations Framework Convention on Climate Change COP 21 (2016), IRENA (2019), INOGATE
Uzbekistan	created Ministry of Energy (2019)	• Strategy on Five Priority Directions for Development in 2017-2021 (2017): - RE by 2025 in electricity generation 20% drafted: • Concept for the Development of RES in the Republic of Uzbekistan for the period 2019-2023 • Concept of Development of the Hydropower Industry for 2020-2024 (2019)	• Law on the Use of RES (2019): solar, wind, geothermal, biomass & HPP (0.2–30 MW) & production of equipment used in RE: —tax exemptions for RE producers: land tax (capacity 0.1 MW or more) for 10 years —manufacturers of RE equipment: exempt from all taxes for 5 years —property & land tax exemption for households: 3 years	• Program of Measures for Further Development of Renewable Energy and Improvement of Energy Efficiency in the Sectors of Economy and Social Sphere for 2017–2021 (2017): —investment requirements: 810 projects, $5.3 bn; $854 mn private; $804.6 mn foreign loans, Uzbekistan's Reconstruction and Development Fund $113.4 mn	Paris Agreement under the United Nations Framework Convention on Climate Change COP 21 (2018), IRENA, INOGATE

Appendix C

Table A3. Index of Economic Freedom 2019 (Source: author, based on Heritage Foundation, https://www.heritage.org/index/explore?view=by-region-country-year).

Country	World Rank	2019 Score	Property Rights	Judicial Effectiveness	Government Integrity	Tax Burden	Government Spending	Fiscal Health	Business Freedom	Labour Freedom	Monetary Freedom	Trade Freedom	Investment Freedom	Financial Freedom
Kazakhstan	59	65.4	59.3	56.1	40.3	93.4	83.7	41.0	73.9	86.2	70.9	80.0	50	50
Kyrgyzstan	79	62.3	49.9	27.9	27.2	94.1	54.2	78.4	73.4	79.8	74.4	78.6	60	50
Tajikistan	122	55.6	47.8	52.1	36.4	91.8	64.6	60.3	67.3	49.2	68.5	73.6	25	30
Turkmenistan	164	48.4	31.6	29.8	20.3	95.9	92.0	92.3	30.0	20.0	73.4	76.0	10	10
Uzbekistan	140	53.3	49.8	34.3	25.2	91.3	67.4	98.7	72.5	58.7	58.9	62.6	10	10

Appendix D

Table A4. ODA in NHRE in Central Asian Economies, US$ mn (Source: author, based on Creditor Reporting System, https://stats.oecd.org/Index.aspx?DataSetCode=CRS1#).

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Kazakhstan		1.52	1.80		0.02	..	0.01	0.01	0.04	0.25
Kyrgyzstan	0.20	1.81	0.32		0.36/14.08 *	..	−/0.02 *	0.01	0.12	0.08
Tajikistan	0.16	5.57	1.25	−/2.03 *	6.88/7.00 *	0.05		0.03	2.80	
Turkmenistan	0.03					0.04	0.11	0.02		
Uzbekistan							0.23	0.09	0.09	0.91

Note: (*) NHRE/RE.

Appendix E

Table A5. Share of NHRE in Total ODA, % (Source: author, based on Creditor Reporting System, https://stats.oecd.org/Index.aspx?DataSetCode=CRS1#).

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Kazakhstan		0.64	2.26		0.03		0.02	0.02	0.07	0.42
Kyrgyzstan	0.15	0.88	0.15		0.17		0.01	0.01	0.06	0.05
Tajikistan	0.09	3.94			2.87	0.03		0.01	2.50	
Turkmenistan	0.23					0.41	0.78	0.34		
Uzbekistan							0.06	0.03	0.17	0.33

Appendix F

Table A6. China's Investments in Central Asian Economies' Energy Sectors, bn US$. (Source: author, based on China Global Investment Tracker and https://renewablesnow.com/country/kazakhstan-569/#, https://renewablesnow.com/news/search/?term=&sections=all&date=all&country=Uzbekistan).

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Energy Share*
Kazakhstan	4.2 O	1.91	1.31 G	0.25	2.6 G 0.94 G	0.73 H	0.85 O	0.15 G 0.5 G 0.36 H 0.19 0.9 G	5.3 O	0.53 O 1.09 O	0.35 O 0.12 O	0.34 RE		0.16 RE 1.5 H	0.14 RE	69.45% (24.42/35.16), oil, gas (2.62% RE)
Kyrgyzstan							0.39			0.39 C 0.43 O 1.4 G 0.28 O						61.10% (2.89/4.73), gas, oil

Tajikistan		0.4						0.35 C							34.88% (0.75/ 2.15)
Turkmenistan			0.15 G		3.13 G			2.92 G		0.6 G					100% (6.77/ 6.8), gas
Uzbekistan			0.88 G					2.04 G 0.23 C				0.15 RE	0.19 G		61.34% (3.49/ 5.69), gas, coal (4.30% RE)

Notes: O – oil, G – gas, C – coal, H – hydropower, RE – renewable energy.;* share of investments in energy (energy investment/ total investments); also, as specified, investments in conventional sources and RE.

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